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J. B. Weems	Chemist
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W. H. Norton	Special Assistant
J. A. Udden	Special Assistant
T. H. Macbride	Special Assistant
Thos. J. Savage	Special Assistant
Ira A. Williams	Special Assistant
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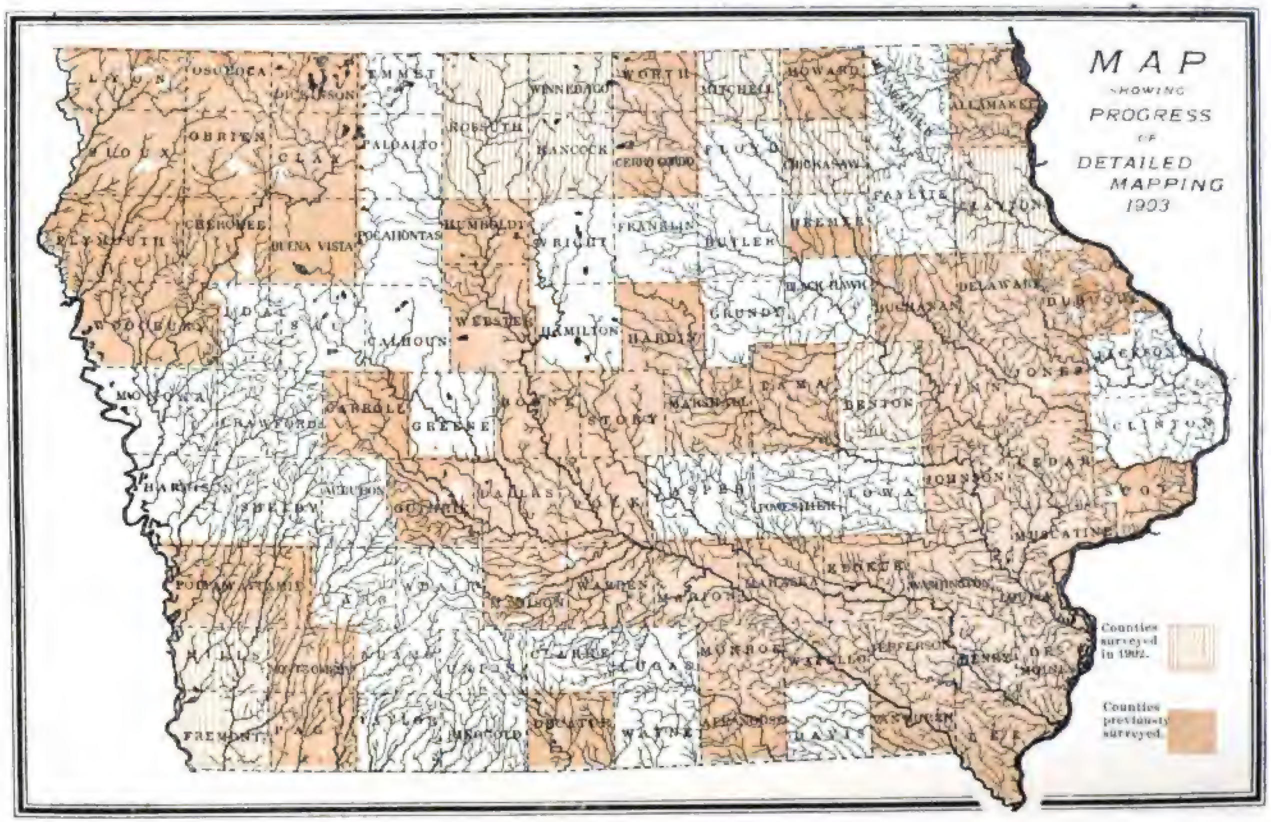
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ELEVENTH ANNUAL

Report of the State Geologist.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1902.

To Governor Albert B. Cummins and Members of the Geological Board:

GENTLEMEN:—I have the honor to report that during the year 1902 the work of the Iowa Geological Survey has been prosecuted in accordance with the plans approved by you at the beginning of the working season. The area covered by the year's work has been larger than during any previous year since the Survey was organized. In carrying out the plan agreed upon, the counties of Kossuth, Winnebago and Hancock were investigated by T. H. Macbride, Mills and Fremont were surveyed by J. A. Udden, Mitchell and Chickasaw by S. Calvin, A. G. Leonard worked in Clayton county and T. E. Savage in Tama and Benton. The work on Monroe and Howard was revised and the completed reports on these counties are now ready for publication. Ira A. Williams devoted some time to completing the field work on the clays and the clay industries of the state, and the monograph on this subject, which has for some time engaged the attention of S. W. Beyer and his associates, is practically ready for the printer. The annual collection of Mineral Statistics for the state, by S. W. Beyer, one of the valuable features of the work of the Survey for a number of years, is continued, and his report is herewith submitted. W. H. Norton has kept up the work of collecting data from deep borings, and has thus

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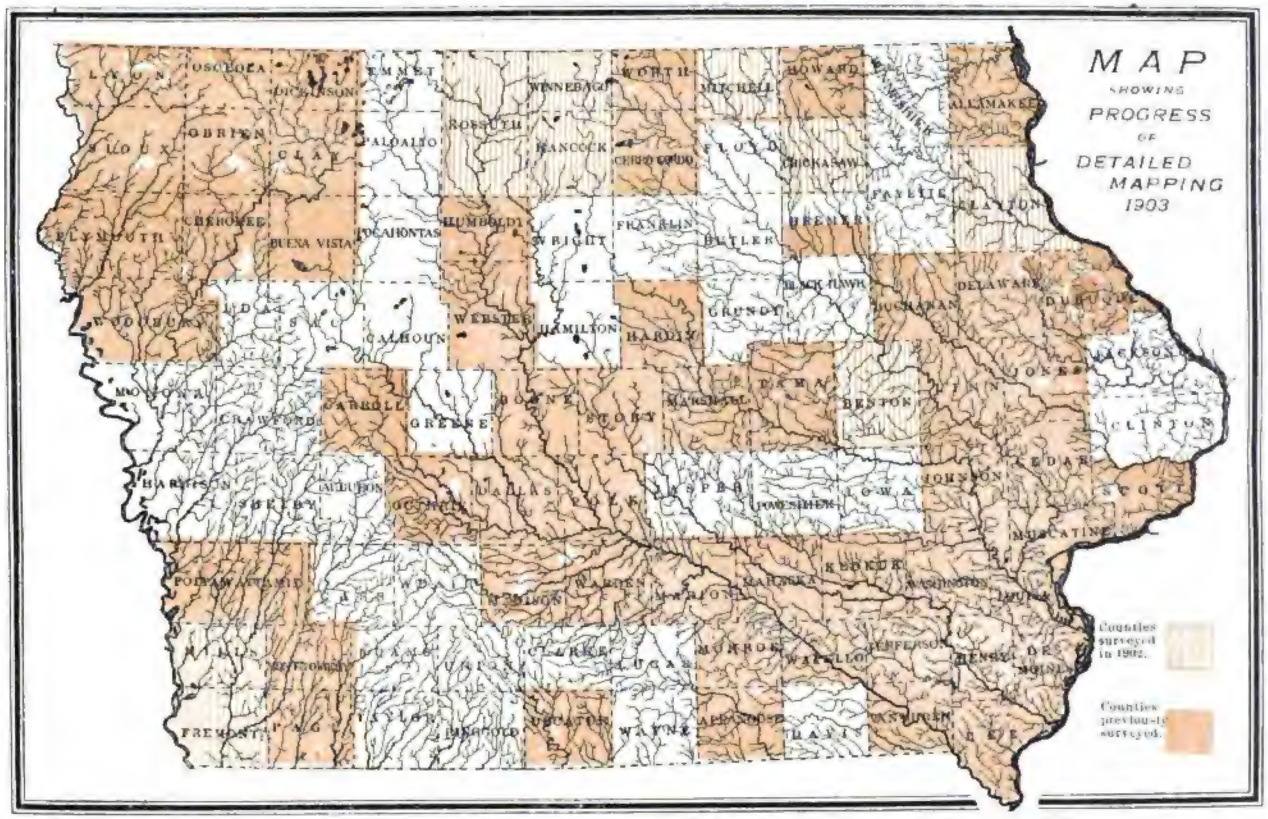
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extended our knowledge of the manner in which the different formations, as they pass farther and farther beneath the surface, vary in respect to thickness and composition. M. F. Arey served as a volunteer assistant in making the Survey of Mitchell county and rendered acceptable and valuable service.

During the year volume XII of the regular series of reports was printed and distributed. The administrative work of the Des Moines office, such as superintending the engraving of maps and illustrations, the printing, proof reading, binding and distribution of the reports, and all the other details that can best be supervised at the state capitol, has been done by the Assistant State Geologist, A. G. Leonard, assisted by the Secretary, Miss Nellie E. Newman.

The work now ready for publication embraces Bulletin No. 2, on the Grasses of Iowa, by L. H. Pammel; the Clays and Clay Industries of Iowa, by S. W. Beyer in collaboration with Professors Weems, Marston and others; and volume XIII of the regular series of reports. For the principal subject matter of volume XIII there are herewith submitted reports on Monroe, Tama, Howard, Mitchell, Chickasaw, Mills, Fremont, Hancock, Winnebago and Kossuth counties. This is the largest number of counties heretofore reported on in a single volume. Mills and Fremont are treated by Professor Udden as a single area, and Hancock, Winnebago and Kossuth are grouped together in one report by Professor Macbride.

As usual the demand for copies of the reports has been far in excess of the supply. The repeated calls for copies of the separate county reports for use in connection with the study of Physical Geography in the high schools, indicates a growing use of the publications of the Survey in ways which insures their highest usefulness to the present and future citizens of the state.

The accompanying map shows the progress which has so far been made in detailed areal work. The counties remaining to be covered are all more or less intimately related to areas that

have been studied, and their investigation can now be made with less labor than would be required if the geological structure of adjacent territory were wholly unknown. The collection of data for monographs on coals, building stones and other special subjects is progressing as rapidly as is consistent with necessary thoroughness.

I have the honor to remain, gentlemen,

Yours very sincerely,

SAMUEL CALVIN.

REPORT OF ASSISTANT STATE GEOLOGIST.

IOWA GEOLOGICAL SURVEY,
DES MOINES, DECEMBER 31, 1902.

SIR:—I have the honor to submit the following report upon the work of the past year. The greater part of my time during the first six months was taken up with the duties incident to the publication of volume XII. As usual the regular work of the office included also the furnishing of information in reply to the many letters of inquiry which are constantly being received. The Survey is in this way able to render a service to the general public and to the various companies and organizations which are in search of information regarding the natural resources of Iowa.

Early in March a trip was made to Frederika where indications of oil were reported to have been found. The sinking of wells was discouraged since the facts did not seem to justify the expense of drilling. The excitement was so great, however, that several companies put down holes in search of oil. It is needless to say that none was found. A trip was taken to Wapello county in June for the purpose of examining some deep cuts along the new line of the Chicago, Burlington and Quincy railroad, two miles east of Ottumwa. It was thought that these cuts, some of which are fifty or sixty feet deep, might reveal the presence of the older drift sheet beneath the Kansan, but it did not appear in any of the sections.

As soon as the completion of the printing of volume XII allowed me to leave the office, field work was commenced in Clayton county and continued through August and September. Much

of this county lies within the limits of the driftless area of northeastern Iowa and southwestern Wisconsin and for countless ages its rocks have been subjected to the erosion of streams and the weathering effects of the atmosphere. The surface is cut by deep, picturesque valleys and gorges, along the sides of which are exposed in succession one rock formation after another. Within this county there occur a greater number of different geological formations than can be found in any other county in the state. It also contains representatives of some of the oldest strata in Iowa. Some of these furnish a very pure white sand suitable for glass making; other beds afford excellent limestone for building purposes and for lime. The areal distribution of the various limestones, sandstones and shales is being carefully mapped with the aid of a topographic map prepared by the United States Geological Survey.

During the past year the following publications have been added to the library of the Survey.

Mineral Resources of South Dakota. South Dakota Geological Survey, Bulletin No. 3.

Geological Survey of New Jersey. Annual Report of the State Geologist for 1901.

Geological Survey of Georgia. Bulletin No. 8. Roads and Road Making Materials of Georgia.

Missouri Botanical Garden. Thirteenth Report, 1902.

Twenty-first Annual Report United States Geological Survey, Parts II, III, IV.

Bulletin United States Geological Survey, Nos. 177-187.

Jahrbuch der Königl, Preussischen geologischen Landesanstalt und Bergakademie.

Proceedings of the United States National Museum, Volume 24.

Verhandlungen der Naturforschenden Gesellschaft in Basel, 1901.

Verhandlungen der Schweizerischen Naturforschenden Gesellschaft, 1901.

Mittheilungen ans dem Mineralogischen Institut der Universitat Bonn, 1901.

Actes de la Société Helvétique des Sciences Naturelles, 1900.

Mineral Resources of New South Wales. Pittman.

Annual Report of the Minister of Mines, British Columbia, for 1901.

Transactions of the American Institute of Mining Engineers, Volume XXXI. 1902.

Geological Survey of Louisiana. Report of 1902.

Wisconsin Survey. Bulletin No. VIII. Lakes of Southeastern Wisconsin.

Annual Report of the Smithsonian Institution, 1901.
Maryland Geological Survey, Volume IV.
Mineral Resources of Kansas, 1900 and 1901.
Proceedings and Collections of the Wyoming Historical and Geological Society for 1901.

Very Respectfully,
A. G. LEONARD,
Assistant State Geologist.

TO PROFESSOR SAMUEL CALVIN,
State Geologist.

REPORT OF PROF. W. H. NORTON, IN CHARGE OF ARTESIAN WELLS.

Professor Samuel Calvin, Ph. D., State Geologist:

SIR:—I have the honor to present the following report of the work of this office during the year 1902.

A complete and trustworthy set of sample drillings from the deep well at the Iowa Hospital for the Insane at Mt. Pleasant was obtained in January, thus giving us a clear geological section of the deeper strata in this area.

In February the office was asked by the Board of Control of State Institutions to supply to the General Assembly an estimate of the depth, strata penetrated, probable quantity and quality of water, and cost of a proposed artesian well at the Hospital for the Insane at Independence. The detailed estimates submitted were in all respects favorable to the drilling of the well, and were made with great confidence, based on the geology of the deeper formations of the region.

The Board of Control also consulted us on several occasions during the progress of the work of sinking the deep well at the Hospital for the Insane at Cherokee, particularly as to the advisability of continuing the boring to greater depths. An excellent record and set of drillings was supplied from this important well, which shed much light on the geology of a region which is so heavily mantled with drift that the place and relations of its stratified rocks have been far from plain. Within the moderate depth of 1,070 feet a supply of about 60 gallons per minute was secured, and the thickness of the Saint Peter, which was here found about 70 feet thick, and the quantity of water which it carries encourage the sinking of other wells in the region. An analysis of the water showed that it was heavily charged with minerals in solution and clear of all organic matter, a result altogether to be expected. No injurious effects are to be apprehended from

its use at the hospital as the minerals dissolved are chiefly calcium and magnesium carbonates with some sodium sulphate.

We were also consulted during the year by the council of the city of Grinnell as to prosecution of the work in drilling a second artesian for the city supply.

To this report as to artesian wells, I may add that early in the spring I was called to Bremer county, whose survey I have nearly completed, to advise as to the location of a deep boring which a company was about to put down at Frederika in search for petroleum. For some months previous—to give the briefest sketch of the circumstances—oil had appeared in two shallow wells of the town, and on this basis two or more oil companies were formed, the lands about the village were leased, and several thousand dollars of stock were sold. An analysis of the oil at the State University had proved it refined kerosene, destitute of either a paraffine or an asphaltum base. And on a personal investigation the source of the oil was clear. The two wells were situated on either side of a general store in which a considerable quantity of kerosene was stored, one being about ten feet away and the other about ninety feet distant. Frederika is built on the sand and gravel terrace of the Wapsipinicon river, underlain at a depth of about ten feet with Devonian limestone. I found that from one of the tanks in the cellar of the store just mentioned there had been a recent considerable leakage, besides the drip which naturally takes place where oil is often drawn from faucets. The quantity of oil which had been pumped from the wells had been greatly exaggerated, and it was with entire confidence that I reported to the company that "in part or whole the kerosene in the wells is due to leakage" and that "the possibility of oil below the surface at Frederika which has not passed through the hands of the Standard Oil Co. is so slight as to be negligible." It was also pointed out that the attitude of the strata beneath the village,—either a syncline, or a contiuous dip to the south,—discourages any search for oil. Considerable confidence had been placed in two reported oil springs, on the river bank, one above and one below the town, as the theory of leakage from the cellar could not apply here; but a careful search failed to find any trace of such springs.

Unfortunately, my advice was received too late; the contract had already been made for the deep well, the foreman was on the ground and the machinery on its way. As is well known, the same advice, given by different members of the Survey, although discredited at the time in several of the leading newspapers of the state, has been amply confirmed by the event. A somewhat expensive experience and some interesting drillings saved from the borings remain as the valuable assets of the oil companies which exploited the Frederika oil field. I should add that so far as known there is not the slightest evidence of fraud on the part of the companies that sold stock and bored the wells. The work of investigating the field was undertaken by them in good faith and with laudable enterprise, but like so many other exploitations for oil and coal and precious metals, in neglect of, or opposition to, the advice of geologists who use the large experience and knowledge gathered by many men in many fields in the settlement of local problems.

I remain your obedient servant,

WILLIAM HARMON NORTON.

Cornell College, Mt. Vernon, Iowa, Jan. 24, 1903.

REPORT OF DR. J. B. WEEMS.

AMES, IOWA, January 22, 1903.

Prof. Samuel Calvin, State Geological Survey, Des Moines, Iowa:

SIR:—I have the honor of making the following report for the Chemical Work of the Survey for 1902.

The work has been limited to the chemical and rational analysis of clays in connection with the investigation of the clays of the state. The samples which have been received have been analyzed and it is hoped that the results will be in suitable form for publication in the near future.

The co-operative work on the soils of the state is also well advanced and the present indication is that the work will be completed during the coming year.

Respectfully submitted,

J. B. WEEMS,
Chemist.

GEOLOGY OF HOWARD COUNTY

BY

SAMUEL CALVIN

GEOLOGY OF HOWARD COUNTY.

BY SAMUEL CALVIN.

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INTRODUCTION.

LOCATION AND AREA.

Howard belongs to the northern tier of counties and is the third in order counting westward from the northeast corner of the state. With reference to the distribution of the geological formations of Iowa, its location is one of unusual interest. Along the Upper Iowa, or Oneota river, in Albion township, Howard county possesses some of the characteristics of the Driftless Area, a unique area which includes a large part of Allamakee county and parts of Winneshiek, Fayette, Clayton, Dubuque and Jackson. From this area Howard county is separated by a narrow marginal zone of Kansan drift. The border of the Iowan drift passes through the northeastern part of the county, and so northeast of the Iowan boundary the country is rolling Kansan drift covered with loess, while by far the larger part of the county, lying southwest of this well defined line of division, belongs to the level or gently undulating, uneroded, loessless Iowan plain. One of the interesting geological features of this region is the absence of the Niagara limestone or any representative of the Silurian system, for here the Devonian overlaps upon the shales and shaly limestones of the Maquoketa stage of the Ordovician. The margin of the overlap and the contact of the Devonian with the Maquoketa may be studied at various points within the limits of the county now under consideration.

The artificial boundaries of Howard county are the state of Minnesota on the north, Winneshiek county on the east, Chickasaw on the south and Mitchell on the west. The county is divided into twelve civil townships. The four southern townships, as organized for the administration of local government, are nine miles long from north to south, and so each embraces one congressional township and a half. The northern townships are each only five miles in length from north to south, sections 1 to 6 in each case being omitted. The other four townships are

of the usual size. The county is a rectangle, the dimensions being approximately twenty miles from north to south and twenty-four miles from east to west. The area is therefore 480 square miles more or less, the variation from the theoretical area depending on the natural convergence of north-south lines and errors in the original surveys.

PREVIOUS GEOLOGICAL WORK.

Previous to the organization of the present Survey, Howard county received but little attention at the hands of official geologists. In connection with the survey made by Hall & Whitney during portions of the years 1855, 56 and 57, the northern counties of the eastern part of the state were hastily examined by J. D. Whitney for the purpose of determining their leading geological features, without, however, attempting anything like detailed investigations. In the report* which followed the references to Howard county are very meager and relate almost wholly to the position, importance and courses of the drainage streams. The report of Dr. C. A. White † makes no reference to the county we are now considering; but in 1872 Dr. White read a paper at the Dubuque meeting of the American Association for the Advancement of Science ‡ in which he discussed the geological significance of fossils found in the drift of Howard county near Lime Springs. McGee in his Pleistocene History of Norheastern Iowa ‖ makes a number of references to the topography, drainage, indurated rocks and glacial deposits of Howard county. Geologists and paleontologists have long been attracted by the interesting fauna which may be collected from outcrops of the Trenton and Maquoketa formations along the Upper Iowa, or Oneota river, above and below Florenceville, in the northeastern part of the county; and on this account there are frequent references in geological literature to the rocks and fossils of the Florenceville region. In the report on Fillmore

*Report on the Geol. Surv. of the State of Iowa: By James Hall and J. D. Whitney; Vol. I. Pt I, pp. 306-312, 1858.

†Report on the Geol. Surv. of the State of Iowa: By Charles A. White, M. D.; Vols. I and II. Des Moines, 1870.

‡On the Eastern Limit of Cretaceous Deposits in Iowa: By C. A. White. Proc. Am. Ass'n for the Adv. of Sci. Twenty-first Meeting. p. 187, Cambridge, 1873.

‖The Pleistocene History of Northeastern Iowa: By W J McGee. Eleventh Ann. Rept. U. S. Geol. Surv., p. 189 et seq., Washington, 1891.

county, Minnesota,* the rocks of Howard county, especially those about Lime Springs, receive more or less attention in the way of comparison of outcrops in Iowa with outcrops on the other side of the state boundary. The Devonian limestones of the area under discussion in this report are very highly dolomitized and, lithologically, they resemble certain phases of the Niagara beds farther south. While some of the exposed sections are rich in casts of fossils, there are others which are quite barren, and the result has been that nearly all the writers mentioned above, either in printed text or published maps, have referred some of the dolomitized Devonian to the Niagara series. The overlap of the Devonian on the Maquoketa is something unlooked for, unexpected.

PHYSIOGRAPHY.

TOPOGRAPHY.

The loess margin of the Iowan drift plain passes through the northeast part of Howard and divides the county into two very distinct topographic areas, each of which is again divided into smaller areas according to the extent to which the glacial deposits are developed. The line separating the two principal areas passes from Minnesota into Iowa near the northwest corner of section 11, Forest City township, from which point it bends to the west and then turns nearly due south, traversing the eastern edge of section 10. After passing into section 15 the line makes an abrupt bend to the east, passes through the northern part of section 14, whence, veering southward, it maintains, with some minor deflections and sinuosities, a general southeasterly course until it leaves the county a few rods south of the northeast corner of section 36, Albion township. The area north and east of this line is comparatively small; only about 22 square miles, all told, are here included; but within this limited space there is more of varied topographic interest than in all the rest of the county. On one side of the line, in the smaller area, the surface deposits are Kansan drift overlain by loess; on the other side the surface is occupied by a young drift sheet, the Iowan, upon which there is no loess, but large granite bowlders of types wholly

*The Geology of Fillmore County: By N. H. Winchell: The Geology of Minnesota. Vol. I, of the Final Report, pp. 268-324: Minneapolis, 1884.

absent from the northeastern part of the county, give character to the long vistas of gently undulating plain. The small northeastern area may be called the *Loess-Kansan,* the larger area to the southwest is the *Iowan.*

The Topography of the Loess-Kansan Area.—Excepting the valley of the Upper Iowa, or Oneota river, the surface of the Loess-Kansan area presents a series of rounded hills separated by ravines which have been cut by flowing water. Stream action is the dominant characteristic of the region. All its present topographic features—the hills, ravines and even the deep river valleys—are due to the carving and shaping effects of ordinary surface drainage. Outside the river valley and its immediate tributaries, the topography is a direct product of the run-off of the ordinary storm waters. The underlying drift, as already intimated, is what has been called in recent geological literature the Kansan. The surface of this ancient glacial deposit, by reason of long exposure to rains and other meteorologic agents, was deeply trenched, and the sculpturing resulted in producing, on a small scale, a mature type of erosional topography. (Fig. 1.)

FIG. 1. Erosionally developed and well rounded hills of the Loess-Kansan area, in the northeastern part of Howard county.

At the time of maximum development of the ice sheet which deposited the comparatively recent Iowan drift, the carved surface of the old Kansan till, outside the border of the Iowan ice, was covered with a thin veneer of the fine clay called loess. This loess was moulded over the inequalities of the eroded Kansan surface. The deposit was doubtless thicker in some places than in others, but, after all, the thickness was practically uniform, the variations being no greater than would be found in a mantle of snow laid down in comparative quiet upon an uneven surface. And so it was that by the deposition of the loess the characteristics of the old topography were not veiled or obscured to any noteworthy extent. The hills and ravines into which the drift surface had been carved were not changed, but retained the same positions and the same relative heights during and after the process of loess deposition. It is true that some minor features of the topography of this region are due to trenches cut in the recently deposited loess, but in general the amount of erosion since the loess was laid down as a mantle over the trenched surface of the Kansan drift is so small as to be scarcely appreciable. This fact becomes the more evident when the Iowan area is studied, for, except in a few very limited portions of the Iowan plain where conditions have been unusually favorable to the action of erosive agents, the surface of the younger drift, which in age is contemporaneous with the main body of the loess, remains practically as the glaciers left it. Over nearly the entire extent of its area, the amount of erosion that took place in the surface of the Iowan drift between the retreat of the Iowan ice and the occupation and cultivation of the territory by the white man, would have to be expressed by zero. Except in a very few unimportant details, therefore, the topography of the Loess-Kansan region is not due to erosion of the loess, but is controlled by surface forms which had been developed long before any loess was deposited. All deep cuts, for roads or railways or for whatever purpose made, in Loess-Kansan areas of Iowa, whether in Howard county or in other portions of the state, show that the present loess surface is essentially parallel with the old eroded surface of the Kansan till. The reader will pardon the apparently unnecessary reiteration involved in the statement that all field

evidence is overwhelmingly in favor of the view that the topography of Loess-Kansan areas, such topography as is shown in figure 1, is fundamentally pre-loessial. The loess never filled the valleys and trenches and levelled up the surface as some have supposed. Its thickness and relations to the surface have never been very different from what they are today.

Over the greater part of the Loess-Kansan area of Howard county, the surface forms have been developed by erosion of a sheet of drift. A marked departure from the type of topography generally prevailing in the region is found in the charmingly picturesque valley of the Upper Iowa, or Oneota river. This valley is a deep trench cut into the indurated rocks (Figs. 2 and 3). The rock-cut gorge is in places comparatively narrow, its depth ranges from 75 to 125 feet, the walls are steep, it resembles in some of its characteristics the valleys of the Driftless Area. As to age, the topography of the greater part of the northeastern division of Howard county is post-Kansan, having been chiefly developed, as already noted, by erosion of the drift surface during the long intervals between the retreat of the Kansan ice and

FIG. 2. View in the valley of the Upper Iowa, or Oneota river, in the northeast quarter of section 11, Albion township.

FIG. 8. The rock-walled gorge of the river in the southeast quarter of section 12, Albion township.

the deposition of the loess. On the other hand the rock-cut valley of the Oneota is much older than the Kansan, it is evidently preglacial. There are no indications that this part of Iowa was ever occupied by the ancient ice sheet that, over the major portion of the state, preceded the Kansan; but that the valley was deep and open as it is today when the ice of the Kansan stage was melting is attested by terraces of rusty Buchanan gravel at various points along the stream. A concrete illustration of these old gravels, deposited by floods from the melting Kansan ice and rising but little above the level of the water in the present channel, is found south of the bridge at Florenceville, near the middle of section 10, Albion township. The margin of the valley rises to an altitude of about 100 feet above the surface of the terrace. It is in sections 11 and 12 of this township that the most picturesque features of the Oneota valley, features most nearly allied to those which characterize the Driftless Area, are developed.

Topography of a mixed type, partly preglacial and in part due to erosion of Kansan drift, occurs in the south half of sections 11 and 12, and in sections 13, 22, 23 and 24, Albion town-

ship. The same type, indeed, occurs in small areas on both sides of the river as far west as section 10, Forest City township. The surface in these localities is quite generally covered with Kansan drift, but the drift is so thin and so meager that the present topography is largely controlled by the erosion which had taken place in the preglacial rock surface.

The Topography of the Iowan Area.—The Iowan area embraces much the larger part of Howard county. There was a time, however, when the whole county, and practically the whole surface of Iowa, presented an appearance topographically like the northeastern part of Albion township. The period during which the surface of the old Kansan drift was carved and sculptured by agents of erosion was of unknown duration, but manifestly it was very long as compared with all post-glacial time. At a date very recent compared with the age of the Kansan drift, glacial conditions recurred; a new ice sheet, coming from the northwest, flowed over the eroded Kansan surface, obliterating the old erosional topography as far as it went, and leaving the surface, when the ice melted, in the form of a gently undulating plain. Constructive work of glacial ice in spreading out and piling up morainal detritus was the potent factor in developing the resulting topography. Erosion was in no way concerned. Erosion has not effected any general modification of the surface since the glacial ice disappeared from the region.

The ice sheet which, in this part of Iowa, followed the Kansan and modified the surface of the older drift, was the Iowan. Iowan glaciers covered all of Howard county except the few square miles of the Loess-Kansan area already described. The Iowan ice advanced to what is now the boundary line between the two topographic areas of the county and there stopped. On one side of that line the topography is old, on the other side it is young. Along the boundary line there is usually a great thickening of the loess; and as ordinarily seen from the Iowan plain the margin is marked by a series of hills which, from a distance, present the appearance of a terminal moraine (Fig. 4). From the summit of the marginal ridges the observer looks in one direction upon a tumultuous series of erosionally developed and well rounded hills and ridges (Fig. 1); in the other direction

FIG. 4. Hills of thickened loess, like morainal ridges, along the border of the Iowan plain, in the southern part of section 26, Albion township.

the landscape is an uneroded plain stretching away to an uninterrupted horizon, as level as a sea (Fig. 5).

FIG. 5. Iowan plain in section 7, Oak Dale township, spreading away to the horizon, as level as a sea.

The typical characteristics of the Iowan plain are best illustrated on the broad, flat divides between the drainage courses. The region having its center at the southeast corner of Saratoga township, may be cited as a concrete example of the ideal Iowan plain. But all portions of the county lying southwest of the Iowan-Loess boundary, and not immediately adjacent to streams, present essentially the type of topography illustrated in figure 5. The surface is everywhere a plain, diversified with long, low, sweeping undulations. Such inequalities and irregularities as are present are due to the manner in which the drift material was arranged by the action of the Iowan glaciers, and not to any subsequent carving or shaping by drainage waters. Drainage is as yet very imperfectly developed. There are no definite drainage channels in these inter-stream areas. The storm waters simply flow off along the broad, shallow, concave sags which gradually blend into the gentle swells of low, flat eminences representing the higher and more perfectly drained portions of the surface.

The streams of the Iowan area, in the western three-fourths of the county, flow in shallow depressions broadly concave from side to side, the margins of the depressions blending imperceptibly into the general Iowan plain. This is the condition presented by the Wapsipinicon and Little Wapsipinicon in Afton township, and by Crane creek in Saratoga, Howard and Paris townships. These valleys are all, in a sense, remnants of a pre-Iowan, even of a pre-Kansan, topography which has been modified by deposits of drift. The streams are following ancient valleys which are almost completely filled. Along all these streams there are beds of ferruginous, highly oxidized Buchanan gravels which show that here were drainage courses when the Kansan ice was melting. The gravels rest on Kansan drift with which the old valleys, probably preglacial, were partly filled, and are in turn overlain by Iowan drift. The gracefully curving surfaces of valleys and uplands are sprinkled with Iowan bowlders. The Upper Iowa, or Oneota river, above Chester, occupies a broad-bottomed, imperfectly drained valley which is somewhat sharply set off from the adjoining uplands by a low terrace of Buchanan gravels. The old preglacial valley which was followed

by the post-Kansan drainage and is still followed by a post-Iowan stream, was not so completely filled with the drift of the two recognized ice invasions as were some of the other preglacial valleys of the county. Both of the known drift sheets of this territory become much attenuated toward their margins, in the direction of the Driftless Area. Both are exceedingly variable with respect to the amount of material deposited in different localities. In some places the Kansan drift is thicker than the Iowan. In other places the reverse is true.

Along the Turkey river in the eastern part of the Iowan area, there is a region of very thin drift, and the old preglacial topography expresses itself in spite of the fact that twice at least, the surface had been overflowed by glacial ice. Beginning at Vernon Springs, the valley of the Turkey river is a deep, rock-cut gorge of the preglacial type, excavated in Devonian limestones. There is a small amount of drift over the hills; but the indurated rocks crop out in many places, and the surface of the hill slopes is strewn with untransported fragments of native limestone (Fig. 6). A few bowlders of both Kansan and Iowan

FIG. 6. Region of thin drift at Vernon Springs. The topography is preglacial, the rocks are but partially concealed, and blocks of the native limestone are scattered over the hill slopes.

types may be recognied amongst the loose surficial materials. From Cresco south to the north line of section 35, Vernon Springs township, the country is a typical Iowan plain. South of the point named the region becomes hilly; the Iowan drift thins out; knobs of thoroughly oxidized Buchanan gravel of Kansan age appear, even on the uplands; and the surface, carved into rounded rocky prominences, descends to the river valley which, at New Oregon, is more than 100 feet deep measured from the upland plain. The village of New Oregon is built on a terrace of old rusty Buchanan gravel, the structure of which is well shown a short distance west of the north end of the bridge. The gravel terrace shows that the valley, with practically its present depth, served as a drainage course to carry off the waters from the melting Kansan ice. That it served the same purpose when, later, the Iowan ice was retreating is attested by fresh stratified sands on land of W. H. Patterson, in the east half of the southwest ¼ of section 34, Vernon Springs township. The hilly area dominated by preglacial topography embraces a zone a mile or more in width on each side of the Turkey river, from Vernon Springs to the east line of the county.

Another region of unusual topography embraced in the Iowan area, occurs north of the road leading through the middle of sections 22, 23 and 24, Forest City township. This locality is within a short distance of the Iowan margin. Both drifts here are thin, and numerous stony knobs or low tors project above the general surface. The land is hilly as compared with the ordinary Iowan plain, and furnishes another example of topography controlled by preglacial erosion of the indurated rocks.

DRAINAGE.

The drainage of Howard county follows courses which were determined to a large extent in preglacial time. In places the ancient valleys were only partially filled with drift. In other places they may have been completely filled, but the settling of the loose detritus gave rise to depressions along which the later streams established themselves. The Upper Iowa, or Oneota river, is the most important stream in the county; it has its rise in the Iowan drift plain of Mower county, Minnesota, enters

Howard near the northeast corner of Oak Dale township, takes an unusual course for Iowa streams, nearly due east, and follows a valley characterized by entrenched meanders which are best developed east of the Iowan boundary at Foreston. All the northern townships of Howard county are drained by the Upper Iowa. The tributaries of this stream are, however, few and unimportant. In Albion township, where the valley is cut deeply into the rocks, the river is fed by numerous springs which represent rather shallow underground drainage. The sources of the Turkey river are found in the ill drained depressions of the Iowan plain in Howard Center and Paris townships. There are no well defined drainage channels about the headwaters of the several branches of this stream. The run-off simply follows the broad, shallow sags which were left in the surface by the melting ice of the Iowan glaciers. Below Vernon Springs the valley of the Turkey takes on preglacial characters similar to those seen in the Upper Iowa valley in Albion township. The more typical Iowan area which occupies the southwestern half of the county, is drained by Crane creek and the branches of the Wapsipinicon. Nearly all the streams of this area have their origin within the limits of the county, and they are practically branchless, so far as development of definite tributary channels is concerned. Broad "sloughs," in place of eroded creek beds, serve to collect the waters from the adjacent slopes. While the drainage courses seem to have been determined by the position of preglacial valleys, the streams of the southwestern part of Howard county have accomplished very little in the way of erosion. They have neither valleys nor flooded plains in the ordinary sense. They run in simple shallow trenches cut only a few feet below the level of the surface on which they began to flow after the withdrawal of the Iowan ice.

STRATIGRAPHY.

General Description.

The geological formations exposed in Howard county are not very numerous. The Ordovician and Devonian systems are represented in the indurated rocks, and two divisions of the Glacial series—the Kansan and the Iowan—are recognizable in the sur-

ficial or Pleistocene deposits. The country rock is completely hidden from view by deep accumulations of glacial drift, over approximately nine-tenths of the area of the county. There are a few points, principally in the northeastern townships, where the rock comes to the surface in the general uplands, but it is along stream courses that exposures chiefly occur. The best natural sections are seen in the valley of the Upper Iowa or Oneota, in the Loess-Kansan area east of Foreston. Sections of seventy-five or eighty feet in height occur in sheer cliffs at a few points along the river, and others of less range are not uncommon. There are also some satisfactory sections along the Turkey river, east of Vernon Springs. In other parts of the county rock exposures are few in number, of very limited range, and usually far apart, and so the correlation of the outcrops and the arrangement of them in a definite section are matters of great difficulty. This difficulty, so far as concerns the Devonian, is heightened by the fact that the beds have been altered by dolomitization. In the process of alteration the fossils were reduced to imperfect casts or were entirely obliterated, and so the aid that paleontology might render in correlating outcrops is not always available.

The overlap of the Devonian on the Maquoketa is one of the remarkable features of the stratigraphy of this part of Iowa. The Niagara limestone, which elsewhere intervenes between the formations named, is here absent, and both the Devonian and the Maquoketa of the region differ lithologically from outcrops of corresponding age at the localities where the formations are typically developed and have been most carefully studied. The Devonian is so largely dolomitic that some portions of it resemble certain phases of the Niagara. The Maquoketa is more calcareous than at the well known outcrops in Dubuque county; some of it is even dolomitic and might be mistaken for the Galena limestone, while other parts are more like the non-dolomitized Trenton. The phase of the Devonian which rests on the Maquoketa is not the lowest Devonian of other parts of Iowa, but it is made up of beds carrying *Productella subalata* Hall, and *Spirifer pennatus* Owen, fossils which indicate a horizon near the top of the Wapsipinicon stage. The relations of the strata sug-

gest that, on account of local subsidence after the beginning of the Devonian, the shore line was slowly carried eastward during the time represented by the Coggan, Otis, Independence and Lower Davenport beds, as these are described by Norton in the reports on Linn and Scott counties. The greatest eastward extension of the Devonian sea occurred during the Upper Davenport age, when beds containing the fauna represented by *Productella subalata* and *Spirifer pennatus* were laid directly upon Maquoketa or Hudson River deposits containing *Leptaena unicostata, Plectambonites sericea, Orthis testudinaria* and *Orthis kankakensis.*

The study of the Niagara limestone in counties southeast of the area we are considering—in Fayette, Delaware and Buchanan—shows a decided tendency on the part of this formation to become thinner toward the northwest. It may be possible, therefore, that no Niagara was ever deposited as far north as Howard county. On the other hand there is a possibility that the Niagara is present in its proper position underneath the later deposits, some distance west of the overlapping edge of the Devonian. Owing to the dolomitization of both formations, the Devonian and the Niagara, in the northern part of the state, cannot be differentiated in the ordinary borings from wells; but the combined thickness of the beds above the Maquoketa in wells begun in Devonian limestones at Waverly, Sumner, Frederika and Osage, is so small as to indicate the actual thinning and practical disappearance of the Niagara in this direction.

The following table shows the stratigraphic relations of the geological formations recognized in Howard county:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvial.
		Glacial.	Iowan
			Kansan.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.
			Wapsipinicon.
	Ordovician.	Trenton.	Maquoketa.
			Galena-Trenton.

Ordovician System.

GALENA-TRENTON.

The Galena-Trenton is the lowest of the geological formations exposed in Howard county. It is seen in various exposures along the river valley in Albion township, from Florenceville eastward. A short distance above Florenceville the Trenton disappears beneath the level of the bottom of the valley, passing under thin-bedded, calcareous shales and shaly limestones belonging to the stage of the Lower Maquoketa. There is a general discussion of the Galena-Trenton in the chapter on the Geology of Dubuque county, in volume X of the present series of reports. In that discussion it is shown that the dolomitic phase of the formation, which has been called the Galena limestone, is a local characteristic which is best developed in Dubuque county and becomes less and less marked toword the north, and that non-dolomitized beds in the northern counties, which are the exact equivalent of dolomitized Galena, have usually been referred to as Trenton limestone. Certain persistent life zones were recognized in the Dubuque county report, among which the zone of *Receptaculites oweni,* and a zone containing a number of species of large gastropods are among the most prominent.* The place of the Receptaculites zone is about sixty feet below the top of the formation, and the gastropod zone lies a few feet lower.

In Howard county it is the upper part of the Galena-Trenton, beginning a short distance below the gastropod zone, that is represented in the cliffs along the Upper Iowa river. Rising vertically from the water at a number of points on the stream in the east half of section 12, Albion township, are sheer precipices of Trenton limestone, sixty to eighty feet in height; and from twelve to fifteen feet above the base of the scarps the characteristic species of the gastropod zone occur. The rock is gray or drab in color, rather fine-grained, somewhat magnasian but not dolomitic. It lies mostly in thin beds, though some layers near the foot of the exposed sections are eighteen inches in thickness. The fine cliffs (Fig. 7) in the northeast 1/4 of the southeast 1/4 of section 12, show at their base the lowest beds of the formation

*Iowa Geol. Surv., Vol. X, p. 409, and Nos. 8 and 9, Plate 4, opposite p. 410. Des Moines, 1900.

FIG. 7. Cliffs of Trenton limestone in the northeast quarter of the southeast quarter of section 12, Albion township. The layers at the base of the cliff are the lowest beds exposed in the county.

to be seen within the county. There are somewhat similar cliffs (Fig. 8) in the northeast ¼ of the southeast ¼ of section 11. The gastropod zone is here at the foot of the precipice, and Receptaculites occurs about twenty feet above the level of the water. The face of the cliff is seventy feet in height, and the height above low water in the stream is about eighty feet. To the right of the cliff is the mouth of a small, steep ravine in which the successive beds may be studied more successfully than in the cliff itself. The stone is rather fine-grained and grayish toward the base, but about the middle of the section it occurs in heavier, coarser layers which are more magnesian, and in their general characteristics show a closer approximation to the Galena type of the formation. Judging from the position of the Receptaculites zone, the top of the cliff should correspond very nearly with the top of the Galena-Trenton, and this view is supported by facts observed on the receding hill side a little higher up. For

FIG. 8. Cliffs of Trenton in the northeast quarter of the southeast quarter of section 11, Albion township.

some distance back from the brow of the cliff the ground rises in a gentle slope which is covered with glacial material of Kansan age, but at an altitude of twenty feet above the base of the slope there are some beds of fine-grained, calcareous shales belonging to the Maquoketa. Fifteen feet higher there are beds of more typical Maquoketa with *Leptaena unicostata* and *Plectambonites sericea*.

The upper portion of the Galena-Trenton is exposed at the mill at Florenceville. Just below the mill the stone has been quarried to some extent. It shows the following section:

	FEET.
2. Irregularly bedded, fine grained, fossiliferous limestone with shaly partings; some of the layers represented by detached nodules and irregular lenticular slabs of limestone embedded in shale..................	10
1. Regularly bedded stone in layers a foot or more in thickness, without shaly partings, rather coarse-grained, beds cut by definite joints, joint faces pitted and roughened by weathering.............	8

No. 1 of this section furnishes a durable building stone well suited for use in the rough, substantial grades of masonry. The rock is quite magnesian, semi-crystalline, but is not a true dolomite. This member is the equivalent of the coarser beds observed above the middle of the cliff in section 11 (Fig. 8). Excepting some stem segments of crinoids, no fossils were seen in it at this point. A short distance above Florenceville, a few rods north of the old mill in Granger, Minnesota, there is an exposure of beds equivalent to No. 2 of the foregoing section; while less than 100 yards farther north, the heavy quarry beds of No. 1 are seen in place. A large Orthoceras, the *Cameroceras proteiforme* Hall, occurs in the quarry beds. The shaly partings of the overlying beds—the equivalents of No. 2—furnish quite a number of fossil species, among which were noted a small species of Prasopora, *Lingula philomela, Plectambonites sericea* represented by a number of very small individuals, *Leptaena charlottae* and *Orthis testudinaria*. The upper part of the Granger exposure is not represented at Florenceville. It is more shaly than the lower, and some of the thin beds of limestone furnish small specimens of *Rafinesquina alternata* Conrad, and *Isotelus iowensis* Owen. The great amount of shale alternating with thin, sometimes nodular, beds of limestone indicates that the conditions at the close of the Galena-Trenton in this locality, were similar in one respect at least to those which marked the close of the same stage in Dubuque county. The diminished thickness of the calcareous layers and the increased thickness of the shaly partings near the top of the Galena-Trenton, are noted at page 430 and elsewhere in volume X of these reports.

The Galena-Trenton was not seen in Howard county at any points outside of the immediate valley of the Upper Iowa, or Oneota river. There is, however, a very interesting outcrop a rod or two east of the county line, opposite the southeast corner of section 13, Albion township. The point in question is in the valley of Nichols creek and the river is in fact less than one-fourth of a mile away. The interest attaching to this exposure arises from the fact that the beds exhibit perfectly the characteristics of the Galena limestone. They are buff, granular, vesicular, crystalline, dolomitic, massive, ranging up to six feet in thickness

(Fig. 9). The characteristics are unusual in this part of the state and help to emphasize the fact that dolomitization has no formational significance but may be a purely local phenomenon of very limited extent.

MAQUOKETA OR HUDSON RIVER.

The transition from the Galena-Trenton to the Maquoketa in Howard county is not as abrupt as it is in Dubuque. There are here shales alternating with thin beds of limestone in the upper part of the Galena-Trenton, and soft clay shales alternate with thin indurated layers of calcareo-magnesian shale, at the base

FIG. 9. Typical Galena phase of the Galena-Trenton opposite the southeast corner of section 18, Albion township.

of the Maquoketa. Some of the beds of harder shale in the Maquoketa would rank as argillaceous limestone. The lithological differences between the top of the Trenton and the base of the

Maquoketa are simply differences in the characteristics of the more indurated beds. In the Maquoketa the stony layers are lighter colored, softer, more granular, much more earthy and argillaceous than those of the upper part of the Galena-Trenton. The calcareo-magnesian beds of the Maquoketa, however, are counted of sufficient value to be quarried for building stone, one of the quarries so operated being located on the north side of the river in the southwest ¼ of section 8, Albion township (Fig. 10). The river flows north through the western part of the northeast ¼ of section 9, less than half a mile west of Florenceville, and on the east side of the stream rises a vertical cliff of more or less indurated shales of the Maquoketa stage, sixty to seventy

FIG. 10. Exposure of Maquoketa shales in the southwest quarter of section 8, Albion township.

feet in height. This is the best single section of the formation in the county. Cliffs showing beds of the same type, but diminishing in height as the formation is traced up the stream, occur at intervals almost to Foreston. In the western part of section

7, Albion township, and the eastern part of 12, Forest City township, the river flows between bluffs in which the Maquoketa beds rise in vertical exposures to a height of forty feet above the water. The upper parts of the bluffs in this locality are everywhere composed of Devonian dolomite. The Maquoketa finally disappears beneath Devonian, in the bottom of the river valley, one-half mile east of Foreston.

The general characteristics of the Maquoketa or Hudson River formation, as seen in the valley above Florenceville, are well illustrated at the quarry in the north bank of the stream in the northeast ¼ of section 8. Figure 10 shows the relative thicknesses of the harder and more stony layers compared with the soft, shaly partings. The beds that are sought for building stone rarely exceed four inches in thickness. The intervening seams of shale are equally as thick. All the beds yield readily to the weather, and the cliff face breaks down rapidly. All the surfaces which have been exposed to the air for any length of time, are bleached to a light gray. Fossils are not very common. It is true that some of the beds are crowded with the comminuted stipes of graptolites in such condition that neither genera nor species can be recognized. Occasionally, however, there are perfect individuals which indicate the presence of such common Hudson River types as *Diplograptus pristis; Diplograptus putillus and Diplograptus quadrimucronatus.* The second species is included on the authority of the *Geology of Minnesota,* Vol. III, Part 1, p. 82. Other fossil forms occurring sparingly are *Plectambonites sericea,* small forms of *Rafinesquina alternata, Orthis testudinaria, Isotelus gigas* and the rather short and broad trilobite with rounded cephalon and pygidium which Clarke has described in the *Geology of Minnesota,* Vol. III, Part II, as *Isotelus susae**.

*The *Isotelus susae* Whitfield species, Geology of Wisconsin, vol. IV, p. 236, is a very different form from the one referred by Clarke to this species. It is a smaller, more convex, thicker in front than posteriorly, with the anterior part of the head deflected so that near the front margin the surface of the glabella stands nearly at right angles to the general plane of the body—characteristics correctly shown in Whitfield's Figure 8, Plate 10. The eyes are more prominent, the visual surface is larger than in the species figured and described by Clarke, and the posterior limb of the glabella is much narrower in proportion to its length. In the collections of the University at Iowa City, there are three specimens of Whitfield's and Calvin's *Asaphus* (*Isotelus*) *susae*, from the Florenceville region, but they are all from the upper part of the Galena-Trenton. So far the species has not been found in the Maquoketa or Hudson River shales. In the same collections there are three specimens of the very different form referred to *Isotelus susae* in volume III of the Minnesota Survey, which are from outcrops of the Maquoketa shales on the river above Florenceville. If this broad, short, flat species of trilobite, so well figured and described by Clarke in the Geology of Minnesota, Vol. III, Part II, p. 708, requires a distinctive name, it may be called *Isotelus florencevillensis* in honor of the small village near which it is found.

Distribution.—The distribution of the Maquoketa or Hudson River deposits is not limited, as is the case with the Galena-Trenton, to the walls of the immediate valley of the Upper Iowa river. A broad tongue of Maquoketa crosses the county line from Winneshiek, in sections 13, 24 and 25, and extends up the valley of Nichols creek and its tributaries to near the west line of section 22. There is another tongue of Maquoketa, but smaller than the preceding, projecting into sections 12 and 13, Vernon Springs township. The Maquoketa comes very near the county, if it does not quite enter it, in the valley of the Turkey river. At the bridge over this stream on the county line, there are exposures of the Productella beds of the Devonian, and the Devonian is continued down to the level of the water; but less than one-half mile east of the county line the Maquoketa rises fifteen or twenty feet above the bottom of the river channel, and so it is fairly probable that the formation would be found beneath the water in the stream and the soils in the bottom of the valley, in sections 1 and 12, New Oregon township.

Typical Exposures.—The lower part of the Maquoketa in Howard county, for a thickness of about 60 feet, is composed of the thin, indurated, calcareo-magnesian beds with alternating shaly partings, illustrated at the quarry in section 8, Albion township. Near the top the formation varies greatly, and the characteristics of the same horizon are quite different in different localities. The details of the upper part of the formation are best studied outside the limits of Howard, in Winneshiek county, for the reason that the greater number of exposures found here afford better opportunities for observation. For example, a section embracing the upper forty feet of the formation is seen along the south line of section 16, Lincoln township in Winneshiek. In part the rock of this section is a magnesian shale, and in part it is a crystalline dolomite resembling the Galena limestone at Dubuque. The fossils recognized here are Lingula, a fragment too imperfect to be identified specifically, *Leptaena unicostata, Plectambonites sericea, Orthis testudinaria* and *Orthis kankakensis.* The locality is especially interesting for the reason that the ground rises gradually toward the east, and near the southeast corner of the section named there are dolomitized beds

containing Devonian types of Stropheodonta, Productella, Atrypa and Spirifer. The locality is especially interesting as showing very clearly the absence of the Niagara limestone and the superposition of the Devonian on the Maquoketa.

Along the county line road, on the east side of section 13, Vernon Springs township, the hill slope leading from the south into the valley of Silver creek shows, at the top, the Productella beds of the Devonian, beneath which there are light yellow magnesian shales and harder layers of granular dolomite belonging to the Maquoketa. The shaly magnesian beds begin, in descending the hill, between twenty-five and thirty feet above the level of the small valley. Diligent search failed to reveal any fossils in them, but their relations to other recognizable horizons in the Maquoketa leave little doubt that they represent the transition beds at the top of the formation, described in the reports on the counties of Delaware and Dubuque. On the north side of Silver creek the Devonian, with its usual Productellas and Spirifers, begins not more than ten feet above the floor of the valley, and there is no trace of the light colored magnesian Maquoketa. Here are indications of an unconformity. The creek valley widens rapidly in Winneshiek county, and in its floor and sides are many interesting exposures of Maquoketa, some of which are within a few feet of overlying Devonian. A short distance east of the southwest corner of section 16, New Orleans township, there is an outcrop of non-dolomitized limestone crowded with *Plectambonites sericea* and other Ordovician species. This outcrop recalls the crowded fossiliferous slabs of limestone so common everywhere in the upper part of the Maquoketa, a few feet below the transition beds, in Dubuque county. Thin layers of limestone similarly charged with the common Plectambonites occur at various points in sections 13, 14, 23, 24 and 25, Albion township. An outcrop of upper Maquoketa along the north line of the northeast ¼ of section 8, has numerous individuals of *Streptelasma corniculum* associated with the Plectambonites. The most interesting assemblage of fossils occurs in what are practically the very uppermost beds of the Maquoketa, on the east line of the southeast ¼ of section 25. At this point there are the magnesian transition beds noted in section 13, Vernon Springs township,

but associated with them are some non-dolomitic layers rich in well preserved fossils which are identical in form, size and general expression with corresponding species from the Cincinnati shales of Ohio and Indiana. The Cincinnati types here include robust forms of *Rhynchotrema capax, Rafinesquina alternata* and the varietal form, *R. nasuta*. There are other species, such as *Orthis testudinaria* and *Plectambonites sericea,* which do not vary in many other exposures in Iowa from the forms occurring in the Cincinnati shales. The fossil bearing layers are pure limestone, some of them being completely crinoidal.

Correlation and Thickness.—The Maquoketa formation is much thinner in Howard county than it is in Dubuque. The lower indurated beds with numerous graptolites, exposed in the river valley above Florenceville, may be correlated with the hard, slaty, graptolite-bearing shales which make up the Lower Maquoketa in Dubuque county. The heavy body of plastic shales which compose the greater part of the Upper Maquoketa in the Dubuque county report, seems to be absent from Howard county, the upper member of the formation being represented only by the calcareous, fossiliferous layers and the magnesian transition beds which lie above the plastic clays farther south. The whole thickness of the Maquoketa does not here exceed 100 feet, while in Dubuque county the thickness is fully twice as great.

Devonian System.

GENERAL DESCRIPTION.

The Devonian rocks of Howard county are all calcareous; all are more or less magnesian; the greater portion of the entire system would be classed as impure dolomite. True shales were not observed anywhere. Dolomitization of the Devonian is more common in the northern part of the state than at the southern outcrops in Johnson, Cedar, Muscatine, and Scott counties, thus reversing the rule that has been observed in relation to the dolomitization of the Galena-Trenton. The lowest beds seen in Howard county belong to a horizon far about what has been recognized as the base of the Devonian in the southern part of the area of its distribution. The beds which rest directly on the Maquoketa

contain *Stropheodonta demissa* Conrad, *Productella subalata* Hall, *Atrypa reticularis* Lin., *Atrypa aspera* Schlot., *Spirifer pennatus* Owen and *Cyrtina hamiltonensis* Hall. The fauna indicates a horizon equivalent to that represented about the middle of the quarries at Independence in Buchanan county. In this zone in Howard county, Productella is the most abundant and most characteristic fossil, and it is convenient to refer to the horizon as the *Productella beds*. This zone belongs to the Upper Davenport beds of Norton, below which, before reaching the base of the Devonian in Linn, Cedar and Scott counties, there are the divisions of the Wapsipinicon stage which have been described as Lower Davenport, Independence, Otis and Coggan.

There are here some interesting and puzzling anomalies in the distribution and vertical range of certain species, which are deserving of notice. For example the Productella beds have a thickness of forty feet, a thickness more than twice as great as that of the corresponding beds at Independence. They are overlain by fifteen to twenty feet of coarse dolomite characterized by the inclusion of large masses of crystalline calcite. In these coarse, calcite bearing beds there are occasional casts and impressions of *Favosites alpenensis* and *Acervularia davidsoni*. These corals are in their usual stratigraphic relation to Productella, and so far the succession of life zones is in accord with the Devonian section in Buchanan county. But in the Salisbury quarry at Vernon Springs, twenty feet or more above the top of the coarse, coral bearing dolomite, there are layers only slightly magnesian in which *Gypidula comis, Atrypa aspera,* and the lenticular, elongated, finely striated type of *Atrypa reticularis,* known heretofore only from the horizon of the Independence quarries, are well preserved. This particular form of the *Atrypa reticularis* should be found below the coral horizon and never above. Its place is with Productella. At Independence the Gypidula is found, rather sparingly, as high as the beds carrying Productella, but from Independence to Davenport, Gypidula is more characteristic of the Lower Daveport beds than of any other horizon, and yet the Lower Davenport beds are not even represented in Howard county. These forms seem to have re-migrated into this

territory long after they had permanently disappeared from other parts of Iowa.

Typical Exposures.—1, The lowest member of the Devonian section in Howard county, composed of the Productella beds, is typically exposed at the bridge over the Turkey river on the Howard-Winneshiek county line. At the level of the road, at the south end of the bridge, the deposit is soft, yellow, earthy dolomite which is broken into irregular nodules as a result of weathering. The fossils occur only as casts or impressions, but it is possible to recognize *Stropheodonta demissa, Productella subalata, Spirifer pennatus* and *Cyrtina hamiltonensis.* Besides these there are casts of small undetermined gastropods and pygidia of Phacops. It is about twenty-five feet from the level of the bridge down to the water in the river. The slope is covered with waste, but 150 yards west of the bridge the wash of a small intermittent stream exposes the beds to the level of the narrow flood plain. With the exception of one or two layers that have been quarried on a small scale, the rock is soft and easily disintegrated into a yellow sand or marl. The harder layers, which occur about the middle of the section, contain indistinct impressions of a small shell like *Spirifer subumbonus* Hall. The Productella beds are well shown in the river bluffs at a number of points in section 1, New Oregon township. In the northeast quarter of the section there are massive, undecayed ledges of the Productella horizon, forty feet in thickness.

Along the east side of the northeast ¼ of section 24, Vernon Springs township, there are exposures of badly broken and weathered limestone, soft and magnesian, but rich in Productella and the forms usually associated with it. The full thickness of this part of the Devonian column, about forty feet, is indicated by the rather unsatisfactory outcrops on the long sloping hillside. Near the summit of the hill the next higher member of the series is seen, but after passing the crest the Productella beds reappear on the slope descending to the valley of Silver creek. These beds are again seen north of the southeast corner of section 1 in the same township. In Albion township the exposures of the Productella horizon are quite numerous, though they are rather unimportant and unsatisfactory. In the northeast ¼ of

section 36 a small quarry has been worked at this horizon. The beds are also exposed in the northwest $1/4$ of section 27, at a point one-fourth of a mile north of the center of 22, and at numerous other small breaks and outcrops along the Devonian margin, in the northern part of the township.

The most important exposure of the Productella beds occurs at Foreston, near the northwest corner of section 14, Forest City township. As usual in this part of Iowa, the rock is a rough, vesicular dolomite, rather soft and non-crystalline. The bedding planes are largely obliterated, and the fossils occur only as casts. The exposed section is made up of a number of heavy ledges, all very much alike. The beds have been quarried quite extensively, the massive blocks being used in the construction of the mill dam and in other structures where weight and strength are the most desirable characteristics. Figure 11 is a view at the south end of the quarry, showing the massive character of the layers and the rough, vesicular appearance of the freshly broken surfaces. At the north end of the quarry the following section was noted:

FIG. 11. Quarry in the heavy, dolomitized Productella beds at Foreston, in Forest City township.

		FEET.
5.	Decayed ledges badly broken up and divided into comparatively small blocks	8
4.	Coarse, vesicular, undecayed bed, very fossiliferous, casts and impressions of *Productella subalata* common, impressions showing the coarse ribs and strong spines of *Atrypa aspera* numerous, pygidium of Phacops seen occasionally	5
3.	Coarse, pitted layer like No. 4, with many casts of brachiopods among which Productella is the most common	4½
2.	Soft, light yellow bed with casts of *Atrypa reticularis*	3
1.	Bed like No. 2, but softer and more granular, with few fossils, mostly *Atrypa reticularis*, bed divides in places into four parts each about one foot in thickness, in places the parts are fused together on account of the complete obliteration of the bedding planes	4

There are massive ledges of the Productella beds in the steep bluffs facing the river in section 12 of Forest City township and section 7 of Albion. The lower part of the bluffs, for thirty or forty feet, is occupied by the upper portion of the Maquoketa formation, the heavy beds of the Devonian appearing in some places quite conspicuously above the Maquoketa, well up on the steep hillsides. It is the Productella beds that are seen at the level of the water below the mill, at the old town of Lime Springs. Above this point the dip of these beds soon carries them below the level of the stream.

2, The member of the Devonian series which follows the Productella beds in Howard county is the equivalent of the *Acervularia davidsoni* beds of Buchanan county. It is made up of a succession of coarse, dolomitic layers ranging from a few inches to more than a foot in thickness. A typical exposure of these layers shown in figure 12, occurred on the north side of the stream, immediately below the mill dam, at Vernon Springs; and all the way to the east line of the county these beds may be seen in the bluffs of the Turkey river, overlying the Productella horizon. As the county line is approached they are found to occupy a position forty feet or more above the level of the stream. Lithologically these beds resemble certain phases of the Niagara limestone in Delaware and Dubuque counties, except that, in place of the

chert usually found in the Niagara, there are large included masses of calcite. This calcite differs from that which will presently be described as lining spherical or definitely shaped cavities in beds higher up in the series. The spaces it occupies are shapeless and irregular and are completely filled. The formless, cleavable masses are devoid of any indications of crystal faces or crystal outlines.

The exposure at the mill dam (Fig. 12) covers a comparatively large area and gives an unusually favorable opportunity for the

FIG. 12. Typical exposure of the coarse, calcite-bearing beds (Acervularia horizon), below the mill dam at Vernon Springs.

study of the beds in detail. Besides the characteristics already noted, this horizon is distinguished by the presence of casts of *Favosites alpenensis* and *Acervularia davidsoni*. The presence of the corals and the stratigraphic position of the beds both lead to a correlation of the horizon with the *Acervularia davidsoni* zone at Independence, Littleton, Waterloo and Iowa City*. The marked difference in the texture and composition of the rocks and in the perfection and abundance of the fossils are due in part at least to the great changes which were wrought during the process

*Compare the "Coral Reef Bed" in the report on Johnson county, Iowa Geol. Surv., Vol. VII, and the "Acervularia Zone" in the report on Buchanan county, Vol. VIII.

of dolomitization. These coarse dolomitic beds with their shapeless masses of calcite, are seen at intervals, above the Productella horizon, along the east line of the county from section 25, Vernon Springs township, to the north line of section 36 in Albion. They may be recognized, over and over again, in their proper relations, all around the Devonian margin. One of the most fossiliferous exposures of this phase occurs in the side of a ravine near the middle of the west line of section 15, Albion township. The common *Favosites alpenensis* is comparatively abundant. Beds belonging to essentially the same horizon are found in the Croft quarry at Elma, in section 1, south of the middle of Afton township. At the bottom of the quarry there is a dark brownish, crystalline, dolomitic layer which in general forms the floor. It has, however, been taken out over a few square yards; it is very fossiliferous, but the fossils occur only as casts. The forms recognized are *Favosites alpenensis, Stropheodonta demissa, Pentamerella dubia, Atrypa reticularis, Spirifer subvaricosus, S. asper, S. fimbriatus,* a large species of Gomphoceras, and a small species like *G. oviforme.* This fauna belong to a horizon just below the Acervularia zone, and its equivalent in the northeastern part of the county should be included in the lower part of the coarse calcite bearing beds.

3, South of the bridge at New Oregon, above the calcite bearing beds described in the foregoing paragraphs, there are twenty feet of variable strata, composed in part of soft earthy limestone grading into marly shales, and in part of fine-grained, whitish, non-dolomitic limestone. The section is not very satisfactory. In fact the beds of this horizon were not well shown at any point in the county. The non-dolomitic phase of this member of the series is seen in loose, weathered, crackled blocks, a short distance west of the middle of section 24, Vernon Springs township. A better exposure of the crackled beds occurs about eighty rods south of the northeast corner of section 10, and a still better illustration of this special phase is found in the northeast ¼ of section 12, all in Vernon Springs township. In section 12 the beds are rich in stromatoporoids similar to the forms occurring in the stromatoporoid reef from Mitchell, Worth and Cerro Gordo counties on the north, to Johnson county in the southern

7, Albion township, and the eastern part of 12, Forest City township, the river flows between bluffs in which the Maquoketa beds rise in vertical exposures to a height of forty feet above the water. The upper parts of the bluffs in this locality are everywhere composed of Devonian dolomite. The Maquoketa finally disappears beneath Devonian, in the bottom of the river valley, one-half mile east of Foreston.

The general characteristics of the Maquoketa or Hudson River formation, as seen in the valley above Florenceville, are well illustrated at the quarry in the north bank of the stream in the northeast ¼ of section 8. Figure 10 shows the relative thicknesses of the harder and more stony layers compared with the soft, shaly partings. The beds that are sought for building stone rarely exceed four inches in thickness. The intervening seams of shale are equally as thick. All the beds yield readily to the weather, and the cliff face breaks down rapidly. All the surfaces which have been exposed to the air for any length of time, are bleached to a light gray. Fossils are not very common. It is true that some of the beds are crowded with the comminuted stipes of graptolites in such condition that neither genera nor species can be recognized. Occasionally, however, there are perfect individuals which indicate the presence of such common Hudson River types as *Diplograptus pristis; Diplograptus putillus and Diplograptus quadrimucronatus.* The second species is included on the authority of the *Geology of Minnesota,* Vol. III, Part 1, p. 82. Other fossil forms occurring sparingly are *Plectambonites sericea,* small forms of *Rafinesquina alternata, Orthis testudinaria, Isotelus gigas* and the rather short and broad trilobite with rounded cephalon and pygidium which Clarke has described in the *Geology of Minnesota,* Vol. III, Part II, as *Isotelus susae**.

*The *Isotelus susae* Whitfield species, Geology of Wisconsin, vol. IV, p. 236, is a very different form from the one referred by Clarke to this species. It is a smaller, more convex, thicker in front than posteriorly, with the anterior part of the head deflected so that near the front margin the surface of the glabella stands nearly at right angles to the general plane of the body—characteristics correctly shown in Whitfield's Figure 8, Plate 10. The eyes are more prominent, the visual surface is larger than in the species figured and described by Clarke, and the posterior limb of the glabella is much narrower in proportion to its length. In the collections of the University at Iowa City, there are three specimens of Whitfield's and Calvin's *Asaphus* (*Isotelus*) *susae*, from the Florenceville region, but they are all from the upper part of the Galena-Trenton. So far the species has not been found in the Maquoketa or Hudson River shales In the same collections there are three specimens of the very different form referred to *Isotelus susae* in volume III of the Minnesota Survey, which are from outcrops of the Maquoketa shales on the river above Florenceville If this broad, short, flat species of trilobite, so well figured and described by Clarke in the Geology of Minnesota, Vol. III, Part II, p. 708, requires a distinctive name, it may be called *Isotelus florencevillensis* in honor of the small village near which it is found.

Distribution.—The distribution of the Maquoketa or Hudson River deposits is not limited, as is the case with the Galena-Trenton, to the walls of the immediate valley of the Upper Iowa river. A broad tongue of Maquoketa crosses the county line, from Winneshiek, in sections 13, 24 and 25, and extends up the valley of Nichols creek and its tributaries to near the west line of section 22. There is another tongue of Maquoketa, but smaller than the preceding, projecting into sections 12 and 13, Vernon Springs township. The Maquoketa comes very near the county, if it does not quite enter it, in the valley of the Turkey river. At the bridge over this stream on the county line, there are exposures of the Productella beds of the Devonian, and the Devonian is continued down to the level of the water; but less than one-half mile east of the county line the Maquoketa rises fifteen or twenty feet above the bottom of the river channel, and so it is fairly probable that the formation would be found beneath the water in the stream and the soils in the bottom of the valley, in sections 1 and 12, New Oregon township.

Typical Exposures.—The lower part of the Maquoketa in Howard county, for a thickness of about 60 feet, is composed of the thin, indurated, calcareo-magnesian beds with alternating shaly partings, illustrated at the quarry in section 8, Albion township. Near the top the formation varies greatly, and the characteristics of the same horizon are quite different in different localities. The details of the upper part of the formation are best studied outside the limits of Howard, in Winneshiek county, for the reason that the greater number of exposures found here afford better opportunities for observation. For example, a section embracing the upper forty feet of the formation is seen along the south line of section 16, Lincoln township in Winneshiek. In part the rock of this section is a magnesian shale, and in part it is a crystalline dolomite resembling the Galena limestone at Dubuque. The fossils recognized here are Lingula, a fragment too imperfect to be identified specifically, *Leptaena unicostata, Plectambonites sericea, Orthis testudinaria* and *Orthis kankakensis.* The locality is especially interesting for the reason that the ground rises gradually toward the east, and near the southeast corner of the section named there are dolomitized beds

containing Devonian types of Stropheodonta, Productella, Atrypa and Spirifer. The locality is especially interesting as showing very clearly the absence of the Niagara limestone and the superposition of the Devonian on the Maquoketa.

Along the county line road, on the east side of section 13, Vernon Springs township, the hill slope leading from the south into the valley of Silver creek shows, at the top, the Productella beds of the Devonian, beneath which there are light yellow magnesian shales and harder layers of granular dolomite belonging to the Maquoketa. The shaly magnesian beds begin, in descending the hill, between twenty-five and thirty feet above the level of the small valley. Diligent search failed to reveal any fossils in them, but their relations to other recognizable horizons in the Maquoketa leave little doubt that they represent the transition beds at the top of the formation, described in the reports on the counties of Delaware and Dubuque. On the north side of Silver creek the Devonian, with its usual Productellas and Spirifers, begins not more than ten feet above the floor of the valley, and there is no trace of the light colored magnesian Maquoketa. Here are indications of an unconformity. The creek valley widens rapidly in Winneshiek county, and in its floor and sides are many interesting exposures of Maquoketa, some of which are within a few feet of overlying Devonian. A short distance east of the southwest corner of section 16, New Orleans township, there is an outcrop of non-dolomitized limestone crowded with *Plectambonites sericea* and other Ordovician species. This outcrop recalls the crowded fossiliferous slabs of limestone so common everywhere in the upper part of the Maquoketa, a few feet below the transition beds, in Dubuque county. Thin layers of limestone similarly charged with the common Plectambonites occur at various points in sections 13, 14, 23, 24 and 25, Albion township. An outcrop of upper Maquoketa along the north line of the northeast 1/4 of section 8, has numerous individuals of *Streptelasma corniculum* associated with the Plectambonites. The most interesting assemblage of fossils occurs in what are practically the very uppermost beds of the Maquoketa, on the east line of the southeast 1/4 of section 25. At this point there are the magnesian transition beds noted in section 13, Vernon Springs township,

but associated with them are some non-dolomitic layers rich in well preserved fossils which are identical in form, size and general expression with corresponding species from the Cincinnati shales of Ohio and Indiana. The Cincinnati types here include robust forms of *Rhynchotrema capax, Rafinesquina alternata* and the varietal form, *R. nasuta.* There are other species, such as *Orthis testudinaria* and *Plectambonites sericea,* which do not vary in many other exposures in Iowa from the forms occurring in the Cincinnati shales. The fossil bearing layers are pure limestone, some of them being completely crinoidal.

Correlation and Thickness.—The Maquoketa formation is much thinner in Howard county than it is in Dubuque. The lower indurated beds with numerous graptolites, exposed in the river valley above Florenceville, may be correlated with the hard, slaty, graptolite-bearing shales which make up the Lower Maquoketa in Dubuque county. The heavy body of plastic shales which compose the greater part of the Upper Maquoketa in the Dubuque county report, seems to be absent from Howard county, the upper member of the formation being represented only by the calcareous, fossiliferous layers and the magnesian transition beds which lie above the plastic clays farther south. The whole thickness of the Maquoketa does not here exceed 100 feet, while in Dubuque county the thickness is fully twice as great.

Devonian System.

GENERAL DESCRIPTION.

The Devonian rocks of Howard county are all calcareous; all are more or less magnesian; the greater portion of the entire system would be classed as impure dolomite. True shales were not observed anywhere. Dolomitization of the Devonian is more common in the northern part of the state than at the southern outcrops in Johnson, Cedar, Muscatine, and Scott counties, thus reversing the rule that has been observed in relation to the dolomitization of the Galena-Trenton. The lowest beds seen in Howard county belong to a horizon far about what has been recognized as the base of the Devonian in the southern part of the area of its distribution. The beds which rest directly on the Maquoketa

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Along the east side of the northeast 1/4 of section 24, Vernon Springs township, there are exposures of badly broken and weathered limestone, soft and magnesian, but rich in Productella and the forms usually associated with it. The full thickness of this part of the Devonian column, about forty feet, is indicated by the rather unsatisfactory outcrops on the long sloping hillside. Near the summit of the hill the next higher member of the series is seen, but after passing the crest the Productella beds reappear on the slope descending to the valley of Silver creek. These beds are again seen north of the southeast corner of section 1 in the same township. In Albion township the exposures of the Productella horizon are quite numerous, though they are rather unimportant and unsatisfactory. In the northeast 1/4 of

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The most important exposure of the Productella beds occurs at Foreston, near the northwest corner of section 14, Forest City township. As usual in this part of Iowa, the rock is a rough, vesicular dolomite, rather soft and non-crystalline. The bedding planes are largely obliterated, and the fossils occur only as casts. The exposed section is made up of a number of heavy ledges, all very much alike. The beds have been quarried quite extensively, the massive blocks being used in the construction of the mill dam and in other structures where weight and strength are the most desirable characteristics. Figure 11 is a view at the south end of the quarry, showing the massive character of the layers and the rough, vesicular appearance of the freshly broken surfaces. At the north end of the quarry the following section was noted:

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		FEET.
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2.	Soft, light yellow bed with casts of *Atrypa reticularis*	3
1.	Bed like No. 2, but softer and more granular, with few fossils, mostly *Atrypa reticularis*, bed divides in places into four parts each about one foot in thickness, in places the parts are fused together on account of the complete obliteration of the bedding planes	4

There are massive ledges of the Productella beds in the steep bluffs facing the river in section 12 of Forest City township and section 7 of Albion. The lower part of the bluffs, for thirty or forty feet, is occupied by the upper portion of the Maquoketa formation, the heavy beds of the Devonian appearing in some places quite conspicuously above the Maquoketa, well up on the steep hillsides. It is the Productella beds that are seen at the level of the water below the mill, at the old town of Lime Springs. Above this point the dip of these beds soon carries them below the level of the stream.

2, The member of the Devonian series which follows the Productella beds in Howard county is the equivalent of the *Acervularia davidsoni* beds of Buchanan county. It is made up of a succession of coarse, dolomitic layers ranging from a few inches to more than a foot in thickness. A typical exposure of these layers shown in figure 12, occurred on the north side of the stream, immediately below the mill dam, at Vernon Springs; and all the way to the east line of the county these beds may be seen in the bluffs of the Turkey river, overlying the Productella horizon. As the county line is approached they are found to occupy a position forty feet or more above the level of the stream. Lithologically these beds resemble certain phases of the Niagara limestone in Delaware and Dubuque counties, except that, in place of the

chert usually found in the Niagara, there are large included masses of calcite. This calcite differs from that which will presently be described as lining spherical or definitely shaped cavities in beds higher up in the series. The spaces it occupies are shapeless and irregular and are completely filled. The formless, cleavable masses are devoid of any indications of crystal faces or crystal outlines.

The exposure at the mill dam (Fig. 12) covers a comparatively large area and gives an unusually favorable opportunity for the

FIG. 12. Typical exposure of the coarse, calcite-bearing beds (Acervularia horizon), below the mill dam at Vernon Springs.

study of the beds in detail. Besides the characteristics already noted, this horizon is distinguished by the presence of casts of *Favosites alpenensis* and *Acervularia davidsoni*. The presence of the corals and the stratigraphic position of the beds both lead to a correlation of the horizon with the *Acervularia davidsoni* zone at Independence, Littleton, Waterloo and Iowa City*. The marked difference in the texture and composition of the rocks and in the perfection and abundance of the fossils are due in part at least to the great changes which were wrought during the process

*Compare the "Coral Reef Bed" in the report on Johnson county, Iowa Geol. Surv., Vol. VII, and the "Acervularia Zone" in the report on Buchanan county, Vol. VIII.

of dolomitization. These coarse dolomitic beds with their shapeless masses of calcite, are seen at intervals, above the Productella horizon, along the east line of the county from section 25, Vernon Springs township, to the north line of section 36 in Albion. They may be recognized, over and over again, in their proper relations, all around the Devonian margin. One of the most fossiliferous exposures of this phase occurs in the side of a ravine near the middle of the west line of section 15, Albion township. The common *Favosites alpenensis* is comparatively abundant. Beds belonging to essentially the same horizon are found in the Croft quarry at Elma, in section 1, south of the middle of Afton township. At the bottom of the quarry there is a dark brownish, crystalline, dolomitic layer which in general forms the floor. It has, however, been taken out over a few square yards; it is very fossiliferous, but the fossils occur only as casts. The forms recognized are *Favosites alpenensis, Stropheodonta demissa, Pentamerella dubia, Atrypa reticularis, Spirifer subvaricosus, S. asper, S. fimbriatus,* a large species of Gomphoceras, and a small species like *G. oviforme.* This fauna belong to a horizon just below the Acervularia zone, and its equivalent in the northeastern part of the county should be included in the lower part of the coarse calcite bearing beds.

3, South of the bridge at New Oregon, above the calcite bearing beds described in the foregoing paragraphs, there are twenty feet of variable strata, composed in part of soft earthy limestone grading into marly shales, and in part of fine-grained, whitish, non-dolomitic limestone. The section is not very satisfactory. In fact the beds of this horizon were not well shown at any point in the county. The non-dolomitic phase of this member of the series is seen in loose, weathered, crackled blocks, a short distance west of the middle of section 24, Vernon Springs township. A better exposure of the crackled beds occurs about eighty rods south of the northeast corner of section 10, and a still better illustration of this special phase is found in the northeast ¼ of section 12, all in Vernon Springs township. In section 12 the beds are rich in stromatoporoids similar to the forms occurring in the stromatoporoid reef from Mitchell, Worth and Cerro Gordo counties on the north, to Johnson county in the southern

part of the Devonian area. Besides the stromatoporoids the beds carry a small digitate Favosites and the usual gastropod of this horizon, *Euomphalus cyclostomus*. The non-dolomitic, fine-grained, white limestone of this horizon is the equivalent of the beds described as "fine-grained, white limestone" in the reports on Johnson and Cerro Gordo counties. This phase of the Devonian, which is always associated with the stromatoporoid horizon, attains its fullest development in Mitchell county and in the northern part of Floyd, where it takes on the characteristics of a fine lithographic stone. The same lithographic phase, but less perfectly developed, occurs at LeRoy in Minnesota, a short distance from the north Howard county line. This third member of the Devonian series is quite variable. While, in the northeastern part of the county, the non-dolomitic stromatoporoid beds occur in it, these beds are not always present. The greater part of this portion of the section is a soft, magnesian, earthy limestone which breaks down rapidly into a marly clay or into irregular concretionary fragments. The exact line separating this from the next overlying member of the section could not be definitely traced.

4, The beds which follow No. 3 in ascending order are typically represented in the quarries at Vernon Springs. One of these quarries, which was formerly worked quite extensively, is located on land belonging to H. C. Salisbury, in the southwest 1/4 of the southwest 1/4 of section 34, Vernon Springs township. Other exposures occur in the Patterson quarries in the northeast 1/4 of the same quarter section, and in a small quarry near the river in the southwest 1/4 of section 33. At the base of the Salisbury quarry there are several courses of firm bluish limestone not dolomitic. The individual courses are from one to two feet in thickness, and the aggregate exposed is about eight feet. The fossils are mostly brachiopods and the shells are well preserved. Among the species noted are *Gypidula comis, Atrypa aspera* and the fine lined type of *Atrypa reticularis* found in the quarries at Independence. Reference has already been made to the fact that this fauna seems very much out of place in a position above the Acervularia and stromatoporoid horizons. The concurrence of

these special types of brachiopods is unknown elsewhere* except at the horizon of the quarry stone at Independence, a horizon which corresponds to that of the Productella beds of Howard county.

FIG. 13. The Salisbury quarry, near Vernon Springs.

5. In the Salisbury quarry (Fig. 13) the beds last described are overlain by soft, granular, magnesian limestone stained more or less with iron oxide and varying in color from dirty yellow to dull brown and red. This fifth division of the Howard county Devonian has a total thickness of at least fifty feet. It furnishes

*The three species, *Gypidula comis*, *Atrypa aspera* and *Atrypa reticularis*, occur together in the Lime Creek shales at Rockford in Floyd county and at Hackberry Grove in Cerro Gordo, but in all three cases the forms are varietally different from those at Independence. The *A. aspera* at Independence is Hall's variety *A. occidentalis*, while the similar species in the Lime Creek shales has been referred to the variety *A. hystrix*. The *A. reticularis* of the two horizons differs very strikingly in size, markings and general proportions, and the Gypidulas are sufficiently distinct to make their separation a simple and easy matter. The species as they occur in the Salisbury quarry are all of the types found at Independence. These species all persisted somewhere—in the meantime suffering more or less modification in form—during the interval which separated the age of the quarry stone at Independence from that of the shales at Rockford, and the fact that they migrated into Iowa and temporarily occupied some parts of it at different times during the interval, need occasion no surprise. The re-migration which enabled them to occupy Howard county long after they had disappeared from Buchanan, occurred before modification had progressed to any appreciable extent.

the best of the building stone quarried in the county. It is the equivalent of the "Yellow, earthy limestone" quarried near Littleton and described in the report on Buchanan county, (Iowa Geological Survey, Vol. VIII, p. 234). Lithologically the beds are very similar in Howard and Buchanan. The characteristics are unusually persistent.

The Salisbury quarry affords the following section:

		FEET.
5.	Black soil mixed with broken rock	1
4.	Rock in broken, angular fragments affording an illustration of how the stone yields to frost and weather	4
3.	Heavy courses of good building stone, soft, magnesian, yellow or brown in color, containing numerous spheroidal cavities lined with crystals of calcite, fossils rare and represented only by casts	8
2.	Band of softer, more argillaceous limestone in three or four layers, calcite lined cavities numerous	3
1.	Courses of more solid and purer limestone from one to three feet in thickness, fossil shells preserved	7

Number 1 of this section is composed of the beds already described, which constitute the fourth member of the Devonian series, while 2, 3, and 4 represent the lower part of the fifth. All the beds of the quarry are cut at short intervals by oblique joints. The other quarries in the immediate vicinity of Vernon Springs show nothing essentially different from what is seen in the quarry described. In the northwest ¼ of section 33, Vernon Springs township, quite an amount of stone has been taken out, and the opening shows three heavy ledges ,each about three and a half feet in thickness, cut by numerous joints, and presenting many vug-like, or geode-like cavities lined with calcite. The rock resembles No. 3 of the Salisbury quarry, but the beds are higher in the series. The workable layers are overlain by from four to five feet of small, angular, worthless fragments which have resulted from the disintegration of still higher beds.

The largest quarry in the county is operated by John Hallman near the Fair ground, in the western edge of Cresco. It has been opened by working down beneath the surface of the level prairie. In stratigraphic position the beds here lie above any heretofore noted and are probably the highest to be found within our territory. The rock is earthy, magnesian, rather soft, but it seems to

be capable of standing the weather fairly well. At some points, the quarry has been worked to a depth of twenty feet. Toward the top the bedding is quite regular in places for a thickness of eight feet, and the stone may be taken out in courses ranging from three to six inches in thickness. The whole deposit is very irregularly jointed, the joints cutting the beds at every angle from vertical to horizontal. In the lower part of the quarry the bedding is quite irregular, the courses are thicker and they pitch and roll in the most confused way, in different directions. Crushing and movement since the deposit was laid down are indicated by the general development of slickensides on the joint faces. Fossils are very rare. A few impressions of what seemed to be *Stropheodonta demissa* were noted, together with obscure fragments of plates of fishes.

The upper part of the Salisbury quarry and the higher beds exposed in the other openings near Vernon Springs are represented in a small opening from which a considerable quantity of good building stone has been taken, in the northeast ¼ of the southeast ¼ of section 14, Forest City township. The location is on one of the high points in an area of thin drift and consequent preglacial topography. There is not more than six inches of soil above the four foot band of decayed and broken stone which represents the effects of frost and weather. Below the fragmentary band the stone is sound, lies in heavy ledges, is freer than usual from calcite lined cavities and is capable of affording dimension blocks of fair sizes. Much of it is streaked with iron oxide, a feature, however, better shown in the next quarry to be described. The only fossil observed here was an imperfect impression of a closely coiled, nautiloid cephalopod. The same beds are shown in a somewhat extensively worked quarry belonging to M. H. Jones, in the southeast ¼ of the southeast ¼ of section 24, Chester township. The beds are soft, granular and magnesian as usual. They are stained by the secondary infiltration of iron oxide which is arranged in flexuous, concentric, parallel bands around certain nuclei, the disposition of the bands being in no way influenced by joints or lamination planes. The vug-like cavities lined with calcite are common. This completes the observations made on the fifth member of the Devonian

surface between the two points—about seven feet to the mile—is greater than the dip of the strata, and hence it is that the Elma horizon is lower than the horizon of the quarry stone at Cresco. The limestones at Cresco are the highest, stratigraphically, occurring in the county.

The general section of the Howard county Devonian may be arranged in the following divisions:

		FEET.
5.	The quarry beds at Cresco, Vernon Springs, the Jones quarry in section 24, Chester township, and the quarry on high ground in the southeast ¼ of section 14, Forest City township	50
4.	Non-dolomitic beds at the base of the Salisbury quarry and exposed at a few other points, as in section 18, Forest City township, carrying Orthis, Gypidula and Atrypa like forms found in the quarries at Independence	8
3.	Beds varying in character, some of the layers white, fine-grained, lithographic, in some places rich in stromatoporoid corals	15
2.	Coarse-grained, dolomitic beds in the northeastern part of the county, less dolomitic at Elma and southwest, the horizon of Favosites, Acervularia and Pentamerella, the quarry beds at Elma and the country southwest	15
1.	Productella beds, soft, buff colored, vesicular dolomite, with casts of fossils, quarried in massive blocks at Foreston, the real equivalent of the quarry stone beds at Independence	40

Pleistocene System.

KANSAN STAGE.

Kansan Till.—The oldest drift sheet positively recognized in Howard county is the Kansan. In boring deep farm wells on the prairies, partially decayed logs and other remnants of buried forests are found at various depths ranging to 250 feet; but the evidence of a definite forest, peat or soil horizon between two distinct bodies of glacial detritus, is not clear. There is as yet no certainty that the sub-Aftonian or pre-Kansan till is present in the area we are considering, although it is very probable that it exists in the parts of the county covered with deep drift, in

the beds in both quarries may be referred to the horizon of the coarse, calcite bearing member, number 2, exposed at Vernon Springs and shown in figure 12. No fossils were seen above the basal layer of the Croft quarry. The overlying limestone is regularly bedded, coarse-grained, contains large amounts of calcite, lies in layers ten inches to a foot in thickness at the bottom, but, toward the top of the quarry, splits into thin flags two or three inches in thickness.

Beds corresponding to the upper part of the Croft quarry have been worked for building stone at points from three and a half to four miles west of Elma. There is one opening on land of M. Monaghan near the center of section 8, and another on land of J. Roche in the western edge of section 9, in the southern part of Afton township. Both of these quarries were opened in the surface of the level prairie. Neither has been operated for a number of years. Soil has washed down over the face of the layers, and growth of vegetation has helped to obscure the situation. There is another abandoned quarry three-fourths of a mile south of Elma, on land belonging to Henry Miller. A rank growth of weeds and bushes conceals all the layers except one heavy, dolomitic ledge eighteen inches in thickness. This point is higher than the Croft quarry, and the beds are probably equivalent to some part of the third division of the Howard county Devonian.

Thin bedded, coarse-grained, magnesian limestone like that in the upper part of the Croft quarry, is exposed in the banks and bottom of a small branch of Crane creek, in the northeast ¼ of section 33, Saratoga township. At one point a small quarry has been opened, but the stone comes out in pieces too small to be very serviceable.

The Devonian beds show very little dip in any direction. The inclination corresponds very nearly to the general slope of the surface toward the southwest. Chester is fifty feet higher than Elma. The distance between the two points is about sixteen miles. The same beds are exposed at both places. The dip from one point to the other, which is along a line very nearly at right angles to the strike, is but little more than three feet to the mile. Cresco is 118 feet higher than Elma. The inclination of the

surface between the two points—about seven feet to the mile—is greater than the dip of the strata, and hence it is that the Elma horizon is lower than the horizon of the quarry stone at Cresco. The limestones at Cresco are the highest, stratigraphically, occurring in the county.

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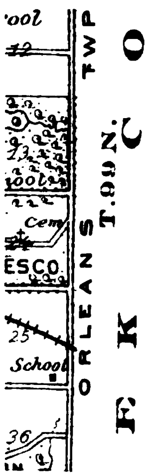


SUPERFICIAL DEPOSITS

OF

HOWARD

COUNTY

Oak Dale, Jamestown, Afton and Howard townships, and in the southern parts of Paris and New Oregon. The Kansan till, overlain by a thin deposit of Iowan loess, is the surficial drift in a comparatively small area in the northeastern corner of the county, and over the larger area southwest of the loess margin it is present beneath the much later drift sheet, the Iowan. The physical characteristics of the two areas and the position of the boundary line between them have been previously discussed under the head of Topography. In the Loess-Kansan area the weathered ferruginous ferretto zone of the Kansan is seen along roadsides and in many other places, wherever rainwash has cut through the overlying loess. At the brick yard in Cresco the yellow Iowan, free from limestone pebbles, is used in brick making, but some of the excavations have gone down to the unweathered blue clay of the Kansan. A deep railway cut one and a half miles south of Elma reveals the Kansan drift in its unweathered phase. A few rods north of a wagon bridge which here spans the cut, the section shows:

		FEET.
3.	Yellow, unweathered Iowan till	6
2.	Old peaty soil developed in the intervals between the Kansan and the Iowan stages of glaciation	2
1.	Blue unweathered Kansan to bottom of the cut	15

There is here no ferretto zone at the surface of the Kansan; the organic material of the peaty soil bed was capable of more than counterbalancing any effects of oxidation which might have taken place before the Kansan surface was covered and protected from further change by the deposition of the Iowan drift. One-fourth of a mile south of the bridge there are a number of lenses of gray sand included in the blue Kansan clay, some of which are three feet in thickness and fifty feet in length. Though the hill in which the cut is made is one of the highest of the region, it shows none of the characteristics of a paha, that unique and interesting type of land forms so common at corresponding distances from the Iowan margin in Delaware, Jones, Linn and Cedar counties. When first seen from a distance it was confidently believed that it would prove to be a loess-covered pahoid ridge, but in the place of loess it is covered with a thin sheet of Iowan

till and its surface is liberally sprinkled with large Iowan bowlders. The fresh Kansan till is here, as everywhere else in Iowa, a blue clay crowded with small pebbles, many of which are limestone. Greenstones are also common. Granites are relatively scarce, and none are as large as the third and fourth rate granites of the Iowan, even when first class bowlders are made to include everything above twelve feet in diameter. The earth taken out is piled on the west side of the Elma cut and covers an area of considerable width. In the few years of its exposure to the air, rains have concentrated the pebbles in a sheet over the surface, by washing away the fine clay in which the pebbles were imbedded. The dump, therefore, now corresponds in a small way to the initial stages of the condition which existed over hundreds of square miles in southwestern Iowa, before the loess was laid down. A sheet of residual gravel, sometimes fully six inches in thickness, conforming to the surface of the erosional hills and valleys, is widely distributed on weathered Kansan underneath the loess, in all the southwestern counties of the state. The fact is discussed and illustrated in the report on Page county. The dump near Elma affords an interesting and concrete illustration of the manner in which these residual gravels were developed.

Wherever there are exposures of the pre-Iowan surface of the Kansan drift, undisturbed by the later glaciation, the materials are found to be very much altered by weathering. The iron bearing constituents of all fine flour and other minute particles derived from wear of crystalline rocks, are completely oxidized, and as a result the normal blue of the unaltered clay is changed to deep reds and browns. The fresh Kansan is always rich in limestone flour and small limestone pebbles. In the weathered zone all the calcareous material, except the larger pieces of limestone, have been dissolved and leached out by descending ground waters. Many of the small granite bowlders have crumbled into minute fragments which are distributed among the other loose materials near the surface, others are ready to fall to pieces under the application of the slightest force.

Buchanan Gravels.—Beds of old weather stained gravels resting on Kansan, and overlain by Iowan drift, were first recognized

as a distinct Pleistocene deposit in Buchanan county, Iowa. Later investigations show these gravels to be extensively developed all over the northeastern part of the state. Howard county has its share, and they are known to be present in the adjacent parts of Minnesota. On one side of the Loess-Kansan border they are generally covered with Iowan drift, on the other side, as is strikingly illustrated around Colesburg in Delaware county, they are overlain by loess. The gravels occur principally in two situations. They are either on the high plateaus and ridges, or they are in the river valleys; and there are very marked differences between the upland and the valley deposits. The upland gravels are distinguished by the presence of coarser and less perfectly assorted materials. Cobbles and bowlders of all sizes up to ten or twelve inches in diameter, are found indifferently mixed with pebbles and fine sand, and many of the larger erratics show glacial planing and striation on one or more sides. While the gravels have all the characteristics of deposits made in flowing water, it is certain that the planed and striated cobbles have not been rolled or transported very far. The valley gravels, on the other hand, are quite uniform as to the size of the pebbles. It is seldom that any of the material exceeds three-fourths of an inch in diameter. The usual size is about half an inch, and the great body of the valley phase is composed of well rounded, polished, silicious pebbles. Cross bedding is more common in the upland, than in the valley gravels.

A very typical example of the upland phase of the Buchanan gravels occurs in the large gravel pit in the southwest ¼ of section 27, Vernon Springs township, about midway between Cresco and Vernon Springs. The material is very rusty from the complete alteration and oxidation of the iron bearing constituents of a large proportion of the crystalline pebbles. In places the amount of iron present is sufficient to cement the gravel into a firm conglomerate. The granites, embracing small bowlders up to eight or ten inches in diameter, are decayed and fall to pieces when taken from their surroundings. Every feature of the deposit indicates age. The gravel at this point has been used extensively for road material. The pit is fully fifteen feet in depth, but it does not show the whole thickness of the deposit. The location

than those developed on the loess. The loess is a fine, porous, calcareous clay, free from sand on the one hand and bowlders on the other. In many respects it makes an ideal soil. It absorbs and retains moisture well. The roots of plants easily penetrate it to great depths. Where the surface is relatively level, a very fine, fertile, brownish, easily tilled loam develops on its surface. On the steeper slopes, however, the loess erodes easily, the vegetable loam is washed away as fast as it accumulates, and steep sided gullies are cut by surface drainage. A hard, stiff, intractable soil usually results from the fact that surface erosion continually exposes fresh loess which has not been modified by the growth and decay of plants, by burrowing animals, by frosts or other mellowing agencies. Fortunately, in the county, the area where soils of the quality last described occur, are small. The farms of the Loess-Kansan area give every evidence of generous production. The porosity and depth of the loess render it capable of successful cultivation in times of drought, such as prevailed in 1901, or during periods of excessive rainfall as in 1902.

(2) There are some small areas of rich, mellow, alluvial soil in the valley of the Upper Iowa river, between Foreston and the eastern border of the county, and a small number of acres of the same type of soil occur in the valley of the Turkey. east of Vernon Springs. Above Chester on the Upper Iowa, at New Oregon on the Turkey, and at many points along the streams draining the southwestern part of the county, the Buchanan gravels come near enough to the surface to produce (3) a gravelly and sandy soil. Buchanan gravels play an important part as subsoils over extensive areas along the branches of the Wapsipinicon in southwestern Howard, giving perfect underdrainage to the surface loams. The typical characteristics of these areas are well illustrated in the level plain from one to two miles west of Elma.

(4) By far the most important of the soil types occurring in Howard county is that which is developed on the Iowan drift. The area in which this type is found is many times larger than that of any other type, and its fertility, ease of cultivation, and lasting qualities set it far above any other. The atmosphere, the rains and frosts of the changing seasons, the growth and decay of plants, the work of the burrowing gophers and ants and earth-

the western edge of section 7, Vernon Springs township, and those in sections 31 and 32 of Howard Center township.

The valley phase of the Buchanan gravels is much more extensively developed than the upland phase. Every stream valley that served as a drainage course when the Kansan ice was melting, is bordered throughout its whole length with trains and terraces of ferruginous gravel in which the pebbles are comparatively small and of uniform size. The terrace on the south side of the river at Florenceville and that on which the village of New Oregon is located have already been mentioned. For some miles above Chester there is a wide, well marked, continuous terrace occupying an area of several hundred acres. The great beds of valley gravels about Le Roy, Minnesota, which the Chicago, Milwaukee & St. Paul railway has used so extensively for ballasting its line, are but part of the enormous gravel trains which floods from the melting Kansan ice strewed continuously along the valley of the Upper Iowa. The same valley gravels are found the whole length of Crane creek and along the branches of the Wapsipinicon, in the southwestern part of the county. In the southeast ¼ of section 1, northern part of New Oregon township, there is a terrace of the valley gravels, some parts of which are cemented into a firm conglomerate. Cementation is not uncommon in other localities.

Genesis of the Gravels.—The Kansan ice was thick, and it melted rapidly, especially when the shrinking margin was gradually retreating through northern Iowa. Large floods of water, capable of transporting great loads of material, flowed outward over the surface which had but a short time previously been vacated by the waning ice. Heavy bodies of the ice must have lingered in the lowlands and valleys long after the hill tops were laid bare, and the re-entrant sinuses in the ice margin, corresponding in position to the higher lands, were drainage channels accommodating torrential streams which were hemmed in by banks of ice. These streams carried material of all grades of fineness up to cobbles and bowlders several inches in diameter. Some of the larger bowlders found in the deposits may have been floated by detached blocks of ice. The heavy material was not carried far, however. With the glacial markings uneffaced

in some cases, it was dropped on the accumulating bars of sand and gravel which the overloaded streams deposited before their exit from the ice canyons. Such imperfectly assorted accumulations, now found on the higher grounds, constitute the upland phase of the Buchanan gravels.

As soon as the upland streams emerged from their ice canyons, the waters sought the lower levels and gathered in the unobstructed valleys beyond the ends of the ice lobes. Before they reached the valleys the heavier material had all been deposited; only the smaller, well rounded and easily transported pebbles were carried, and it is of these that the valley phase is made up. The upland gravels were laid down near the most northerly points of the ice margin, not far from where the streams originated. The valley gravels give evidence of having been transported farther, and they may have been deposited at distances of several miles from the southern extremeties of the lobes of ice which occupied the lower grounds.

IOWAN STAGE.

Iowan Till.—Fully nineteen-twentieths of the area of Howard county is covered with Iowan drift. Where this drift is present in sufficient force to disguise the pre-Iowan topography, the region is a plain modified by only slight relief (Fig. 5). No loess is present, but large granite bowlders (Fig. 15) are prominent features of the landscape. The fresh Iowan till is yellow in color and carries quite a large amount of lime carbonate even at the surface. Among the pebbles limestones and greenstones are rare. The bowlders are coarse-grained and light colored, and it is a surprising fact that in all northeastern Iowa approximately three-fourths of the entire bulk of the Iowan erratics represent but one type of granite which might all have come from a single locality. Iowan bowlders are large and numerous as compared with bowlders in the Kansan drift, but the variety and number of rock species are far greater in the Kansan than in the Iowan.

Over parts of Howard county lying southwest of the Loess-Kansan boundary, the Iowan drift is thin or even absent. As would be expected the thin spots are near the margin where the ice became attenuated and the movement approximated zero.

FIG. 15. Iowan bowlder in the southwest quarter of section 22, Jamestown township. Dimensions above ground are 20x12x9 feet.

The load of glacial detritus carried by the Iowan glaciers seems to have been very unequally distributed, and there must have been places where it was altogether wanting. Quite a large area of thin Iowan, or no Iowan, occurs along the Turkey river from section 31, Vernon Springs township, to section 1 of New Oregon. The original topography developed in the old rock surface by preglacial erosion, is but imperfectly masked by all the Pleistocene deposits. The tops and slopes of the hills are covered with loose fragments of the magnesian Devonian limestone (Fig. 6). The small amount of drift present is of the weathered Kansan type, and yet the surface is strewn with Iowan bowlders. A typical area of thin Iowan, where knobs and tors of Devonian limestone project through the drift, is found in section 14, Forest City township. Bowlders seem to be the only element of the Iowan drift ever deposited in the locality. Along Crane creek and the branches of the Wapsipinicon the later drift is so thin that the Buchanan gravels come practically to the surface in many places, and the same thing is true of the valley of the Upper Iowa above Chester. Taking the Iowan area as a whole, the dis-

tribution of the bowlders seems unaccountably irregular. There are some belts and patches,—as near the center of Jamestown township and in the southern sections of Howard Center,—where the rounded blocks of northern granite are liberally sprinkled over the surface, and again there are areas of miles in extent in which scarcely a trace of a bowlder can be discovered.

Iowan Loess.—The fine, yellow, pebbleless clay called loess forms a mantle of approximately uniform thickness over that portion of the surface of the old eroded Kansan drift which lies outside of the Iowan margin. All that part of the county upon which the Iowan ice advanced, up to the edge and terminus of the glaciers, is free from loess. The loess is fresh and young as compared with the weathered, leached and otherwise altered drift upon which it rests. In this part of the state, it seems very clear, the loess is of the same age as the Iowan till, and was derived from it by some process of transportation outward from the terminal border of the Iowan glaciers. In Mitchell county, as well as in many other counties in Iowa, there are thin deposits of a loess that is younger than the Iowan, probably of the age of the Wisconsin drift. Near Peoria, Illinois, Wisconsin loess is as strongly developed as is the Iowan in Howard county. Loess may indeed, have been formed during any age of the Pleistocene. Along the Missouri river the process of loess deposition seems to be still active. Wherever found, and to whatever age it may belong, it is wholly unlike drift or alluvium,—unlike any glacial, aqueo-glacial, or aqueous deposit known. The origin of the loess of the Mississippi and Missouri valleys has long remained a puzzle to careful and thoughtful geologists. On account of its unique structure, peculiar distribution and fossil contents, the trend of opinion among the best informed students of loess problems is, today, toward the view that it is an aeolian deposit, that winds have been the active agents in its transportation and deposition.

ALLUVIUM.

In Howard county alluvial deposits are very meager. If the Turkey river between Vernon Springs and the east line of the county be left out of consideration, it may be said that throughout the Iowan area the stream valleys in their present aspects

and relations are young. There are here no true valleys of erosion, no flood plains, no notable deposits of river silt. Along the Upper Iowa, or Onęota river, east of Foreston, the valley is old, it is well widened out in places, and there are occasional narrow fringes of alluvial plains between the stream and the bluffs. The same is true, but to a more limited extent, of the old part of the Turkey river valley east of Vernon Springs.

THICKNESS OF THE PLEISTOCENE DEPOSITS.

The sheets of drift and other Pleistocene deposits vary greatly as to thickness. There are two areas where the indurated rocks come near to the surface. One is northeast of a line drawn from Chester to the middle of the eastern boundary of New Oregon township; the other is at Elma and in the country south and west of that locality. All the quarries and rock exposures are in these two areas. At all the quarries the stripping consists largely of disintegrated limestone. Not infrequently the overlying soil, as shown in figure 13, fails to attain the dimensions of a distinct layer. So far as data could be collected, the Pleistocene reaches its greatest thickness in Jamestown township and in the territory immediately surrounding it. Well drillers report that limestone has been struck at 200 feet in the southern part of Oak Dale township, but some wells end in drift at a depth of 300 feet. The well of John P. Thelen in Jamestown township found water in gravel at 252 feet from the surface. Near the center of section 30, Jamestown township, a well in process of boring was down 130 feet and still in blue clay. "Chips of an old rotten log" were reported from a well in the northern part of Jamestown, at a depth of 250 feet. The Pleistocene clays are therefore known to range in thickness from practically zero in the northeastern part of the county, to more than 300 feet in Jamestown and contiguous parts of adjacent townships.

Soils.

The soils of Howard county rank with the best to be found in Iowa. There are (1) loess soils which are limited to the small Kansan area in the northeast corner of the county. Where the surface slopes are comparatively gentle, there are no better soils

than those developed on the loess. The loess is a fine, porous, calcareous clay, free from sand on the one hand and bowlders on the other. In many respects it makes an ideal soil. It absorbs and retains moisture well. The roots of plants easily penetrate it to great depths. Where the surface is relatively level, a very fine, fertile, brownish, easily tilled loam develops on its surface. On the steeper slopes, however, the loess erodes easily, the vegetable loam is washed away as fast as it accumulates, and steep sided gullies are cut by surface drainage. A hard, stiff, intractable soil usually results from the fact that surface erosion continually exposes fresh loess which has not been modified by the growth and decay of plants, by burrowing animals, by frosts or other mellowing agencies. Fortunately, in the county, the area where soils of the quality last described occur, are small. The farms of the Loess-Kansan area give every evidence of generous production. The porosity and depth of the loess render it capable of successful cultivation in times of drought, such as prevailed in 1901, or during periods of excessive rainfall as in 1902.

(2) There are some small areas of rich, mellow, alluvial soil in the valley of the Upper Iowa river, between Foreston and the eastern border of the county, and a small number of acres of the same type of soil occur in the valley of the Turkey. east of Vernon Springs. Above Chester on the Upper Iowa, at New Oregon on the Turkey, and at many points along the streams draining the southwestern part of the county, the Buchanan gravels come near enough to the surface to produce (3) a gravelly and sandy soil. Buchanan gravels play an important part as subsoils over extensive areas along the branches of the Wapsipinicon in southwestern Howard, giving perfect underdrainage to the surface loams. The typical characteristics of these areas are well illustrated in the level plain from one to two miles west of Elma.

(4) By far the most important of the soil types occurring in Howard county is that which is developed on the Iowan drift. The area in which this type is found is many times larger than that of any other type, and its fertility, ease of cultivation, and lasting qualities set it far above any other. The atmosphere, the rains and frosts of the changing seasons, the growth and decay of plants, the work of the burrowing gophers and ants and earth-

worms, have all combined to produce a deep, rich, black, warm soil of ideal quality; and this soil is spread over a surface so level and unbroken that farm machinery of every kind can be operated on its to the very highest advantage.

Unconformities.

Some interesting examples of unconformities are furnished by the geological formations of this part of Iowa. The first and most important is that between the Devonian and the Maquoketa shales. The overlap of the Devonian referred to at the beginning of this report, was a true transgression of the sea upon an eroded surface. The contact of the Devonian with the Ordovician is seen in only a few sections, and these are of limited extent; but the relative altitudes of the two formations at a number of points indicate that the Devonian was deposited on an uneven floor. One or two concrete illustrations will show the nature of the evidence on which conclusions are based. One-fourth of a mile south of the center of section 8, Albion township, magnesian limestone containing remains of fishes and Devonian brachiopods, occurs at a much lower level than that at which undoubted Maquoketa is found along the north line of the same section. At the bridge over the Turkey river near the northeast corner of section 12, New Oregon township,, the Devonian beds are continued down to the level of the water in the stream, while less than half a mile east of the county line Maquoketa shales rise fully twenty feet above the water. Furthermore the phase of the Maquoketa seen in the outcrop referred to is not that which belongs at the top of the formation. The difference in the relative altitudes of the river and the Ordovician strata at the bridge and at the springs a short distance below, cannot be accounted for by either the fall of the stream or the dip of the shales, but by irregularities in the surface on which the Devonian was laid down. Along the east line of section 13, Vernon Springs township, on the hill slope forming the south side of the valley of Silver creek, the Devonian occurs well up toward the top of the slope, and gives place to buff or ash colored Maquoketa about twenty-five feet above the bottom of the valley. On the north side of the valley Devonian rocks in place are exposed less than

ten feet above the small flood plain. How much lower the Devonian may go is not known, for at this point there is no Maquoketa in sight. The other unconformities need only be mentioned without giving specific illustrations. The Kansan drift is unconformable on the rock surface upon which it rests; and the loess and Iowan drift are spread unconformably upon the old eroded surface of the Kansan.

ECONOMIC PRODUCTS.

Quarry Stone.

The northeastern part of Howard county is fairly well supplied with building stone. The Trenton limestone and the shaly limestone of the Maquoketa are both utilized in the vicinity of Florenceville. Figures 7, 8 and 9 illustrate the possibilities of the Trenton as a source of building material. At present the resources of this formation are undeveloped. The only place in the county where it has been quarried to any considerable extent, is at the Florenceville mill; but the Trenton can furnish inexhaustible supplies of a good grade of stone for rough masonry whenever the demand justifies the operation of quarries in this formation. The availability of the calcareous shales of the Maquoketa stage is illustrated at the quarry located one-fourth of a mile northeast of the center of section 8, Albion township (Fig. 10).

By far the greater part of the quarry stone produced in the county is obtained from strata of Devonian age; and practically all the quarries belonging to this age have been previously noted in the general discussion of the stratigraphy. Owing to the almost universal dolomitization of the local Devonian, the building stone from this formation in Howard county is greatly superior to that furnished by beds of corresponding age in the southern part of the Devonian area in Iowa. The beds are here thicker, they are less frequently broken by joints, and they yield less readily to the disintegrating effects of frosts and general weathering. The most important quarry in the county is that operated by Mr. John Hallman in the western part of the city of Cresco. The beds in this quarry are irregularly jointed in places, and the

slickensided joint faces show the effects of crushing. In other parts of the quarry the crushing has been less energetic and destructive, and stones of fairly good dimensions may be taken out. The best layers are soft and easily cut. The product of the quarry includes rubble, range stone and a small amount of cut dimension stone. All the stone produced in the county is used in simply supplying the local demand, and the Hallman quarry has the preeminent advantage of proximity to the best local market. The Salisbury quarry (Fig. 13), Patterson quarry and the many other small quarries near Vernon Springs have not been worked to any noteworthy extent in recent years, although they are capable of furnishing a large amount of very excellent stone. There are at present no shipping facilities, and the local demand does not justify continuous operation.

The quarry at Foreston (Fig. 11), operated in the massive beds of the Productella zone, illustrates the differences in the thickness of beds and the lasting quality of the stone brought about by the process of dolomitization. Bedding planes are obliterated so that what would otherwise be a number of independent layers is blended into one heavy stratum. The quarry represented by figure 1, plate XIV, volume VIII, belongs to the same geological horizon as the quarry at Foreston. In one the joints and bedding planes divide the rock into numberless, small, shapeless pieces which are easily disintegrated; in the other it is possible to get massive blocks of porous but indestructible rock, suitable for the heaviest bridge piers and foundations.

The quarry in section 14, Forest City township, and that in section 24 of Chester are worked in beds corresponding to those in the upper part of the Salisbury and Patterson quarries at Vernon Springs. These beds are equivalent to those quarried at Raymond in Black Hawk county and on the bluff northwest of Littleton in Buchanan county. Other places where stone has been quarried in Howard county are section 33, Saratoga township, and the region about Elma. Of these various openings, the Croft quarry at Elma is at present the most important. All of these quarries in the southwestern part of Howard illustrate varying phases of the coarse, calcite bearing beds at Salisbury's mill (Fig. 12).

Not the least important of the sources of building stone in this part of the state, may be reckoned the numberless granite bowlders of the Iowan drift (Fig. 15). These vary in size up to great blocks twenty or thirty feet in diameter. The amount of indestructible building material present in the glacial bowlders, it would be difficult to estimate. Furthermore the material is ready to hand, requiring no long haulage, on practically every farm in the Iowan area.

Clays.

Howard county is not well provided with raw materials suitable for the manufacture of clay products. It is true that drift clays are widely spread and attain a very great thickness, but they are everywhere filled with such large numbers of pebbles and small cobblestones as seriously to interfere with their use as a basis for any extensive manufacturing enterprise. With suitable machinery for crushing the pebbles it is possible to use the yellow clay of the Iowan drift in making a good grade of structural brick. There is little possibility of using the blue Kansan clay on account of the fact that it contains many pebbles and fragments of limestone. The loess of Howard county is too rich in silica to be used with much success.

The most successful clay working plant in the county is that of the Cresco brick and tile works, owned by Wheeler and Marshall. The clay used is Iowan drift which is passed between rollers to crush the pebbles. The plant is equipped with a stiff mud, end cut Brewer machine having a capacity of 20,000 brick per day. A part of the product is passed through a Raymond re-press machine. In addition to brick the works turn out drain tile ranging from three to eight inches in diameter. The raw product is dried in sheds with little loss from checking. The burning is done in two round down-draft kilns. The plant is operated a little more than half of each year and turns out annually a very respectable amount of mechantable brick and tile.

There is a small brick yard north of the railroad in the eastern edge of Lime Springs. The location was rather unfortunately chosen, for the clay pit shows nothing but blue Kansan clay overlain by from fourteen inches to two feet of Buchanan gravel.

The clay is very pebbly and the pebbles were not crushed. As usual in the Kansan, some limestone fragments are present. The effort to make brick out of such materials was not very sucessful, and the plant was shut down at the time the locality was visited. If there are to be future attempts at brick making in the neighborhood of Lime Springs, the plant should be located at some point where there is a good supply of the yellow Iowan drift.

Lime.

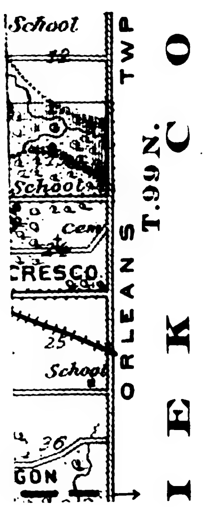
At present no lime is made in the county, but the dolomitic Devonian is capable of furnishing inexhaustible supplies of excellent material for lime burning. Some years ago lime kilns were operated at Vernon Springs and near Lime Springs. The lime made at Vernon Springs was reputed good; that made near Lime Springs is said to have been made from a non-dolomitic rock, which may explain the fact that it was not esteemed so highly. Large kilns at Dubuque and elsewhere, operated on a commercial scale, have driven the small producers out of the local market.

Road Materials.

The Devonian and Ordovician limestones of the county are inexhaustible resources from which supplies of crushed stone for macadamizing streets and roads may be drawn. Not much of this material has as yet been used. The city of Cresco has availed itself of the opportunities offered by readily accessible beds of limestone, and on a small plat of ground at the east end of the Hallman quarry it owns and operates a stone crusher to furnish the macadam used in making permanent street improvements. More widely distributed, more important and more generally useful than accessible ledges of limestone for purposes of road making, are the Buchanan gravels. These furnish material at once inexpensive and of the highest utility and lasting quality. They are everywhere, ready for use as soon as taken from the ground. Every neighborhood may have its gravel pit within easy hauling distance of any piece of road needing improvement.

Water Supplies.

Water for domestic and farm purposes is obtained from the permanent streams, from springs, from wells in gravel terraces, wells in the drift and wells bored into the limestones beneath the drift. Springs are most numerous along the valley of the Upper Iowa or Oneota river. In the Buchanan gravels above Chester water in unfailing abundance is reached at depths of from sixteen to twenty feet,—a little below the level of the water in the adjacent stream. In the region of deep drift in the southern part of Oak Dale, and the northern part of Jamestown township, all the wells, so far as could be ascertained, end in drift at depths varying from forty to 300 feet. In the southwest 1/4 of section 10, Jamestown township, water was found in a layer of gravel beneath blue clay at a depth of 250 feet. Bands of water bearing sand and gravel, lying at various depths between beds of blue clay, are very commonly reported by well borers and seem to be quite universally distributed. Some of the more extensive occurrences of these deep lying sandsand gravels may possibly be of Aftonian age, but the railway cut south of Elma, described in this report, and numerous other drift sections throughout the state, show that it is no unusual thing for the Kansan till to include great lenses of stratified materials having all the characteristics of true aqueous deposits. In the northeastern corner of the county the mantle of loose materials is thin, the limestones lie near the surface, wells are bored into the rock, and water is found in fissures at varying depths. The city of Cresco obtains supplies of water from two drilled wells which do not exceed 200 feet in depth, the water coming from the base of the Maquoketa or the upper part of the Galena-Trenton. A deeper boring at Cresco is referred to by Norton, in volume VI of these reports, page 201, in these words: "The well at this place, owned by the Chicago, Malwaukee & St. Paul Railroad Co., is 1,158 feet deep. It was drilled about the year 1875, and has not been used for an unknown length of time." This well must have gone down some distance into the Saint Croix sandstone. Nothing was ascertained concerning the quality of the water which it furnished.



HOWARD
COUNTY
IOWA.

BY

SAMUEL CALVIN

1903.

[redacted]

Water Powers.

Water power has been developed along the Upper Iowa or Oneota river at a number of points in Howard county. There is a well built and excellently equipped mill at Florenceville; and above Florenceville we find the Foreston, Lime Springs, Glen Roy and Chester mills, all busy in supplying the needs of the local or more distant markets. On the Turkey river there are two mills, the Sovereign mill about a mile above Vernon Springs and the Salisbury mill at the village named. There was formerly a mill at New Oregon, but some years ago the property was wrecked by high water and no effort has been made to restore it.

SUMMARY.

Howard will always rank as one of the great agricultural counties of the state. Apart from her soils her chief geological resources are found in inexhaustible deposits of road materials forming widely distributed beds of sand and gravel, in excellent lime burning rocks which the conditions of the market may some time make it possible to utilize, and in an inexhaustible supply of a fair quality of building stone. As fuel becomes scarcer, and cheaper methods of generating electrical energy are developed, the water powers will be gratly improved and their energy utilized in a variety of profitable ways. There is nothing to indicate the possibility of successful mining of any kind. It is certain that there are no workable coal beds in the county, and there are no probabilities of finding either gas or oil no matter how far borings may be carried. Various lines of manufacturing may possibly be established with success; but the chief resources of the county will always lie in her excellent soils, her chief industry will be their cultivation. It is to the development of the possible productiveness of the soil that the attention of the most earnest and most thoroughly trained minds should be directed. To energy expended in this direction it is possible to predict satisfactory rewards.

GEOLOGY OF

Kossuth, Hancock, and Winnebago Counties

BY

THOMAS H. MACBRIDE

GEOLOGY OF KOSSUTH, HANCOCK, AND WINNEBAGO COUNTIES.

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CONTENTS.

INTRODUCTION.

LOCATION.

The three counties of Iowa here discussed, Kossuth, Hancock, and Winnebago, constitute together an almost perfect square lying along the northern boundary of the State almost midway between the Mississippi and the Sioux. Kossuth is a double county in area, almost the largest county in the State. By our system of surveys the most northern townships and sections in any case bear the brunt of any definciency in land-division; and so it happened that our square is not exactly perfect but measures only about forty-one miles in north and south direction as against forty-eight from east to west.

These three counties are prairie counties, remote from rivers or mountains or any great terrestrial features popularly believed to determine topography, and it would naturally be supposed that all three are just alike, just like fifty other such political divisions to be selected anywhere within our valley-prairies. But such is by no means the case. Greater contrasts are not to be found, within the limits of a region not mountainous, than are to be seen within the square before us. We have plains wide extended, so level that for the passing traveler no inequality can be perceived; towns may hail towns across the unbroken fields and houses dot the distant landscapes like blocks upon a sheet of cardboard. We have precipitous hills rising like miniature mountains directly out of the plain, some of them in groups two or three hundred feet high enclosing lakes, like mountain lakes far above the general level, mantled in native forest and looming blue along the prairie horizon visible for miles and miles; we have townships of alternating marshes and knobby hills without any natural drainage whatever, and we have valleys with gently flowing streams bordered by softly rounded, sloping hillsides perfectly adapted to every phase of agricultural effort.

These are the facts of the problem, facts patent to every comer. The farmers attempt to adapt themselves to the motley situation. Lands suitable to their purposes have been long in use, while only recently the ever increasing demand for farms has impelled men to attempt the tillage of the less tractable hills and swamps. Explanation of the situation is the last thing thought of. Men go doggedly to work to make the best of a difficult problem finding satisfaction in a practical solution, a triumph over physical hindrance, and care only for the ultimate return in wealth or comfort.

Nevertheless there is a solution for our problem, an explanation of these strange conditions,—explanation so simple that anyone may understand it and may safely apply its terms even to the last square yard of all this most singular and anomalous topography.

PREVIOUS GEOLOGICAL STUDY.

It will not be supposed that such solution or explanation has always been at hand ready for each locality fitting thus to such varied local conditions. The facts which lend to our present story credibility have been coming rather rapidly to light during the last five and twenty years, not in Iowa only but in all parts of the northern world. The classification of these facts as set forth in these volumes is even more recent still.. The earlier studies of the earth's surface were concerned in classifying the indurated rocky strata and discovering the history of organic life which these so clearly disclose. Inasmuch as our present field shows nowhere a trace of stratified rock in place these prairies were less attractive, indeed offered nothing to the elder students of the natural history of the State. David Owen about the middle of the last century was at work in this part of the world. He followed the Iowa River until the limestone exposures disappeared along its borders. Fifteen or twenty miles further on he encountered the topography known since his writing as the "knobby drift."* Owen was thus in Franklin county and within a few miles of the territory now discussed. Prof. James Hall, who came next in the order of time, does not mention our counties even by name. They did not fall within the limited scope of his inquiry. It

*Report of the Geological Survey of Wisconsin, Iowa, and Minnesota, David Owen, Phila. 1852, p. 104.

remained for Dr. Chas. A. White to introduce our territory to the world as he does in the second volume of his report.* Dr. White describes in some detail the peculiar topography of Kossuth and Hancock counties, and makes repeated reference to the oft-recurring beds of peat in slough and marsh. It was at that time the opinion of Dr. White and others that peat in the prairie counties would form a very important source of fuel supply. The surface deposits in White's report are simply referred to as drift and no attempt whatever is made to explain either their presence or configuration.

In 1881 the present phase of the geological study of this part of Iowa may be said to take origin in Upham's discussion of the series of morainic hills which all along our northern border extend from Minnesota into Iowa at greater or less length.† Mr. Upham's descriptions are generally accurate and his map as much so as may be expected on the scale to which it is drawn. The morainic field in our particular locality is really much wider than Mr. Upham's map indicates, as will be pointed out in the descriptions here following. In connection with our present study the reader should also consult Professor Calvin's report on Cerro Gordo county.‡

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of the area before us is, as already intimated extremely varied; nevertheless, it is not confused. To the careful observer it will appear that all the at first apparently endless variety is reducible to no more than three distinct types and these are after all quite definitely limited; with respect each to the other mutually exclusive in a remarkable degree. These three topographic types are, first, the type of the level plain, second, that of the knobby drift, the uneroded hills and swamps, and third the type of erosional flood plains and valleys.

The plain is that now familiar in all recent geological literature, the plain of the Wisconsin drift. It marks the bed or path of an

*Report of Geological Survey of the State of Iowa, Charles A. White, M. D., Des Moines, 1870, Vol. II, pp. 246-9

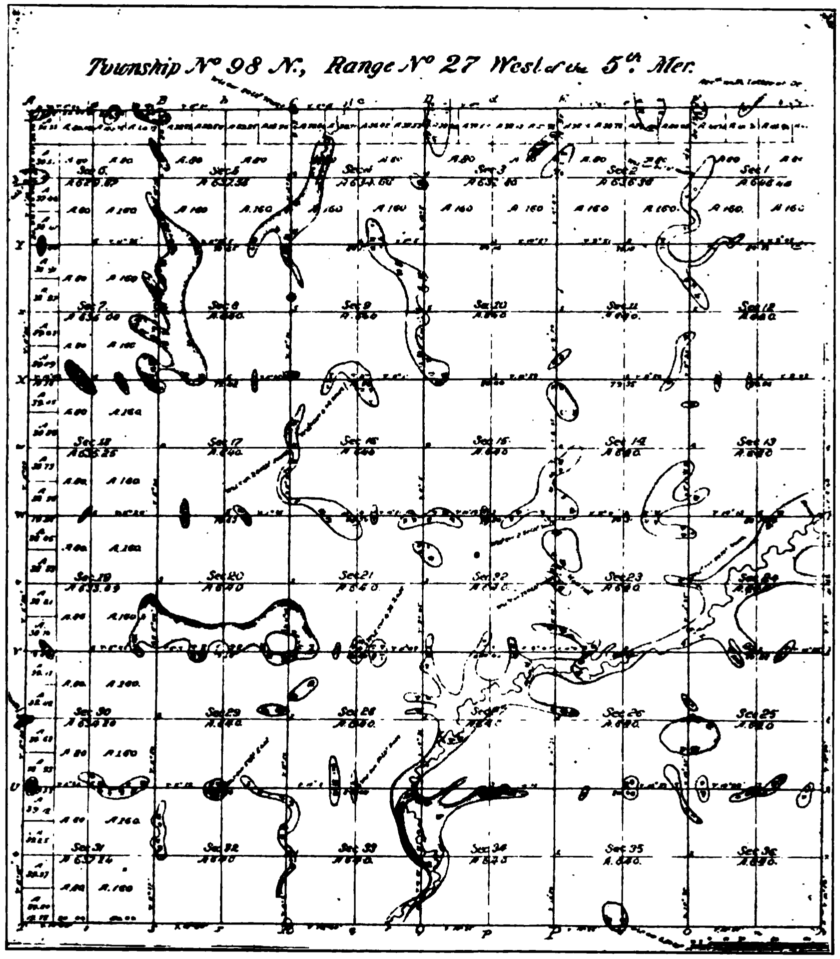
†See Ninth Annual Report of the Geographical and Natural History Survey of Minnesota, pp. 298-314, Minneapolis, 1881, and Plate VI.

‡Volume VII of the present series, pp. 119-193.

ancient extension of arctic ice and snow which at one time descended to our latitude and covered to large extent all the states of Wisconsin, Minnesota, Iowa and the Dakotas. The plain area in the three counties we describe is comparatively limited but its characteristics are as unmistakable as in that region where first this remarkable deposit found distinct recognition and a name. In the first place it is generally almost level. Certainly no one can traverse the southern half of Kossuth or Hancock county without being impressed with this topographic characteristic. Nearly all the western part of Hancock county also is a plain so flat that it seems to show no variation in level whatever. This is particularly the case about Hutchins, Kanawha, Corwith and Luverne. Algona, Wesley, Woden, are on a similar plain but on a different level. As the traveler approaches Woden from the south the village is visible for miles across an unbroken plateau. The valley of Prairie creek, say in Luverne township, is no valley to ordinary vision but an absolute plain stretching to the horizon's rim. These are typical illustrations. Sometimes the plain is marked by here and there a ridge or hill, merely a low swell in the landscape, sometimes a succession of low inequalities may be encountered; but these are recognizable only as one carefully traverses the country roads. Sometimes, as just intimated, the plain breaks from one level to another. This is well shown along a line from Irwington to St. Benedict. In the second place, consequent upon the first characteristic, we have in the plain topography a country without efficient drainage. There has been in many places almost no erosion whatever. The water streams along in sluggish current in some winding depression, sometimes as in case of Prairie Creek south of St. Benedict for considerable distance without any channel at all; sometimes we find a channel which is a mere ditch, tortuous, but only slightly eroded, as in the case of the tributaries of the Boone; sometimes the channel is deeper, a narrow valley has been formed and secondary streams break back in minor shallow receding swales and valleys approaching the erosional type. This is well illustrated by Lotts creek as seen in the township of same name and in Whittemore township both in Kossuth county. The Wisconsin plains have yet another characteristic; they are everywhere

spotted with "kettleholes", small depressions, wet places, an acre, less or more, undrained and grown up, where yet undisturbed by cultivation, to various forms of marsh vegetation, chiefly sedges and bulrushes whose dark colors contrast vividly with the paler vegetation of the surrounding prairie. In dry years the water disappears from most of these marshes and many of them are today lost in cornfields and meadows. But even after cultivation this remarkable surface peculiarity may still be traced. On the beaten pasture field after a summer shower "the rain also filleth the pools" and shines in little shimmering ponds over all the landscape, and for a little the kettle-holes all come back again.

The topography just described passes more or less directly to the north and east into a second type quite as distinct and no less remarkable. As we pass across the plain the horizon is suddenly broken by rounded contours of low mound-like hills, rising to various altitudes, twenty, thirty, seldom exceeding forty feet. As we ascend one of the highest and look about us the significance of Owen's original expression becomes vivid indeed. Here is the "knobby" drift. As far as eye can reach one knob succeeds another, hill after hill, at distances varying, without any relationship to each other or any regularity whatever. They rise out of the plain; they are not carved from it. The larger are apt to occur in groups, and where the sides are steep as is frequently the case, the summits are barren, rocky and gravelly, unfitted wholly for the plough. But if the knobs themselves are peculiar, no less so are the depressions between them. These, too, have little or no relation to each other. No streams run among hills like these; no radiating valleys acknowledge allegiance to these sloping sides. On the contrary, the streams of the country seem to be outside the hills altogether, and the depressions among the knobs are not valleys they are cisterns, lakes, marshes, swamps or pools. Here and there an imperfect drainage channel connects these nearly isolated swamps and we have a winding irregular slough as Mud creek in Kossuth County; sometimes, for reasons to be later on set forth, a considerable stream cuts through the ridges, hills and all, as Lime creek; but in general the depressions among these hills remain undrained or have waited the advent of the county ditch and the skill of the engineer. The accompanying



Plat of township 98 N., range 27 W.

illustration, Plate II, which is a photographic reproduction of the plat of one township as made by the original United States survey, will give some, though a most meager idea of the topography we have here attempted to describe.*

Such in general is the topographic character of all the eastern part of Hancock county, nearly all of Winnebago county and the northern half of Kossuth county. If the flat plain topography represents the bed of the old ice sheet, the knobby drifts marks for us the margin or limits of its occupancy. These hills are moraines, piles of material unspread when the movement of the glacier stopped. In some localities topography of this sort results in unusual features worthy of special description. Not infrequently the marshes are deepened into lakes and the knobs assume sometimes correspondingly commanding proportions. Thus there are lakes in all three of the counties we discuss. In Hancock county are found Twin lakes in the south and Crystal lake at the north and between them Eagle lake; all were at one time notable features of the prairie landscape. All seem to have been meandered and still preserve in large part their original identity. The Twin lakes are small, the larger, eastern, occupying not more than 200 hundred acres. The western lake was at the time of our visit dry, a pasture-field occupied by herds of cattle. Nevertheless there are many indications that it was once a permanent body of water of considerable depth. The banks were in many places high and show the erosion resultant from wave action; on the north these is a distinct sandy beach with recessional ridges, diminutive terraces, etc., all indicating a lengthened history. Nevertheless the history now seems forever closed. The eastern lake contains today the waters of both. In this rainy year of 1902, the waters are by no means deep, and, if one may judge by the extended growth of aquatic plants, bulrushes, sedges and cattails, the eastern lake is also passing and likely at no distant day to become a cultivated field.

Eagle lake is the largest body of water in the three counties. It is about two miles and a half long and half as wide and covers more than one thousand acres. This was at one time apparently

*For further illustration the curious reader may consult the road maps of any of the northern townships of Kossuth county as they lie in the courthouse at Algona. He will find not infrequently as many as six distinct marshes along one side of a given section, interfering with the public road. There are often more than thirty to the square mile.

much more attractive and lake-like than now. The greatest depth at present is said to be eight feet and the areas of open water are few and the greater part, as Twin lake, today grown up with rushes and sedges. Nevertheless there are good beaches here, and cottages have been erected on the western shore. Crystal lake is a permanent body of water beautifully surrounded by groves and hills. It is said to be twenty feet deep; at any rate the depth is sufficient to shut out rushes over the greater part and its clear surface invites the pleasure-seeker's boat.

The lakes of Winnebago county are less important. Rice lake, extending across the boundary and lying chiefly perhaps in Worth county, is a widespread shallow marsh stretching a mile or two in each direction but with only a limited area of open water. Its waters surround an island lifted fifteen or twenty feet above the ordinary level of the water. The island affords a pleasant beach on which cottages have been erected. The lakes of Kossuth county are best described as sloughs or marshes and will no doubt eventually all be drained.

But if the marshes are thus sometimes lakes, the knobs are occasionally no less like mountains. They everywhere surprise us by their abruptness and steepness and in Ellington township of Hancock county, are found two or more which so far transcend all others that they have long been famous. The highest of the group is Pilot Knob* which as the barometer reads is nearly 300 feet above the waters of Lime Creek at its base, 1450 feet above sea level. This is not only the finest morainic mound thus far described in Iowa, but is one of the finest in the whole country. Ocheydan mound is only half so high. The famous Lapham Mound, Wisconsin though more than 800 feet above the level of Lake Michigan is not so high above the basal plain as is our Pilot Knob. The visitor approaches Pilot Knob more easily from Forest City. The mound is visible from the streets of the town (Fig. 16) as indeed from the prairies almost anywhere for miles in any direction looming up dark and blue along the horizon. The highway climbs at first by easy ascent but at length ascends rather

*To the pioneer the boundless prairies of the Mississippi valley seem to have come ever with irresistible suggestion of the sea. The endless meadows of dark grasses driven in waves before the wind established a more vivid likeness and, for the pioneer, any natural object which aided the traveler to find his way across the unmarked plain became a "pilot." Hence Pilot Rock and Pilot Mound and Pilot Knob, over the whole western country.

FIG. 16. Pilot Knob is visible from the streets of Forest City.

abruptly to the western extension of the hill whence the Knob still looms above us nearly a mile further to the east. Between lie mountain meadows, as typically such as if the mountains really rose around us; sedgy bogs girt around by the white ranks of the aspen, walled in by impassable ridges. A tiny lake (Fig. 17) lies to the south 200 feet above Lime creek, fed by springs, cold and clear, in summer decked by water lilies and all forms of northern aquatic vegetation, but the knob is nearly a hundred feet above us still. Forests of oak and ash, linden and hickory spread all around diminishing as we ascend, until we reach the wind-swept summit, perfectly bare; a miniature mountain in every particular. The view from the summit is certainly the finest of its kind. The Knob is so isolated and so steep on almost every side that the prospect in every direction is limited only by the powers of distinct vision. On the plain below us covered, as we know, with hillocks and knobs, all inequalities vanish. The scene entire seems level where houses, groves and towns appear in varied

FIG. 17. Dead Man's lake. A tiny lake lies to the south.

colors to the far horizon's rim. Here is the natural park for the people of Forest City.

Having thus seen something of the nature of the topography with which we deal, we may now take a more comprehensive view and note its general arrangement. It is immediately apparent that there are no knobs to the south and west, and no plains to the north and east. The traveller on the Milwaukee railway approaching from the east meets the knobs at Clear Lake or near it: they keep him company to Britt and then disappear entirely. He has passed through the marginal, or Altamont moraine of the Wisconsin drift in this locality, a distance of some twenty-two miles. If the reader will consult the map of Cerro Gordo county published in this series of reports* he will discover that outwardly, that is, on the eastern side, the moraine terminates by a comparatively uniform front, the line of demarkation between the hill country and the succeeding plain is nearly straight, or at least not very irregular; the inner margin of the moraine is

*Report of the Iowa Geological Survey, Vol. VII, p. 180.

quite the reverse. The ice seems to have returned from north and west again and again as if loth to release its hold, but recession once begun the margin never quite reached again its farthest eastern out-push. By consulting the maps it will be noticed that the existent drainage system is in large measure correspondent to geological history as portrayed. It would seem as if the inner margin of the moraine was first correspondent in general with the eastern bank of Lime Creek and the east fork of the Iowa river. The first return gave us in the same way the west fork of the river and the series of lakes to which we have already alluded. Subsequent advances and retreats presented in each case a somewhat arcuate or V-shaped front extending mainly east and west and leaving as results of marginal drainage the peculiarily paired affluent streams which in Kossuth county especially form the head-waters of the upper Des Moines. It is probable that these later morainic fields will be found coincident with others in Palo Alto and Emmett county which will again unite with those already noted in Dickenson and Clay and so form a more or less continuous recessional moraine across the entire field of Wisconsin invasion in northern Iowa.

A peculiar feature in the topography of Kossuth county may be mentioned here. Extending from the north part of Portland township entirely across Ramsey township and into Ledyard is a deep, well-defined depression known as Union Slough. The banks are in most places precipitous, twenty or thirty feet high and evidently the result of some former erosion. We say former erosion because there is evidently no erosion now. The bottom is flat, a mile at least in average width, without present channel or even drainage; simply a sharply outlined morass or swamp a mile or more in width and ten miles long, shut in by high banks and hills. At present the whole surface is covered with water from one to three or four feet deep, so level that a stream escapes from each end, south into Buffalo creek, north into the Blue Earth river. This trough-like valley is no doubt a section of the channel of some preglacial stream, probably part of the stream now represented by the Des Moines, a part that in some way escaped obliteration, although cut off, especially at the south, by glacial detritus, piles of gravel and sand. It seems probable that Buffalo

creek itself, after passing the south end of the slough, may occupy for a little way, till it reaches the river, part of the same old channel, and possibly the Des Moines also does the same thing here and there in its course southward.

Another topographic feature that is at first sight rather anomalous is the Irvington ridge. A high plateau extends from the river east and north from about Irvington around by St. Benedict and Wesley and so northeast until it joins the morainic hills south and east of Woden. The most prominent margin of the plateau is along the south and follows almost exactly for several miles the section-line road one mile south of the middle of Irvington township. This plateau is only about twenty or twenty-five feet higher than the Hutchins-Britt-Corwith plain, but it is perfectly of forming a correct impression of our extremely level topography. Compare, for example, the Milwaukee line from Garnamed, as Prairie creek in the several branches, find at the plateau-margin a cutting point and erosion has worked back in rather unusual complexity from the crest. The topography looks much older than it really is, for there is no reason to suppose it earlier than the glacial epoch we are discussing. It seems probable that the plateau represents the margin of an advance of the ice sheet which immediately receded, stopping some miles to the north where the knobby-drift region may be first traced and that in this advance either no moraine was left at the south or it has been obliterated by erosion, at first exaggerated by the nearness of the ice-front. The drainage has, however, been always principally toward the Des Moines channel; there is a fall from the eastern crest toward the river of about four feet per mile.

The map accompanying sets forth sufficiently the topography of the region and in the light of what has been said further description seems unnecessary. The supposition that the ice at first moved south and east at the same time and later in a direction almost directly south will probably account for the general trend of the ridges and hills in different parts of the area here described.

On this map the altitude of the railway at the station is entered near the name of each town or village. A comparison of these

altitudes as reported will be very instructive to anyone desirous of forming a correct impression of our extremely level topography. Compare, for example, the Milwaukee line from Garner to Whittemore; or the Northwestern in Kossuth county.

DRAINAGE.

The drainage of the area before us instead of determining the topography is almost entirely determined by it. In some places the drainage is perfect or nearly so; in many places there is no drainage at all. There is however a general slope to the south or southeast and when natural drainage fails it is still possible by ditching to reach the end desired and some of the finest farms in the country border a brimming county ditch.

The naturally drained parts of these counties are in the main those immediately contiguous to the principal streams. Among the morainic hills there are, of course, many well drained fields; but these are often so situated as to make their cultivation difficult until the adjoining marshes are drained or tiled.

The principal streams of the three counties are: the Des Moines river and its tributaries, the Iowa river in two branches, and Lime creek, affecting principally the eastern side of Winnebago county. The Des Moines river, or rather the eastern fork of that stream, takes rise in southern Minnesota and enters Kossuth county from Emmet county some twelve miles south of the State line. The stream is of less importance until joined by its principal eastern tributary, Buffalo creek. From the point of this union some three miles south of the center of Kossuth county the river courses almost directly south through the middle of the county and emerges almost exactly at the center of its southern boundary. The river is a fine perennial stream. The valley of the river from its union with the Buffalo down to the Algona city limits follows apparently an old time channel. The flood plain is wide with much alluvium. At Algona the channel seems to have been pushed west by the drift. At any rate the valley is here new and narrow and is flanked by narrow choppy ravines. Below the city the valley widens again and at Irvington seems to have been at one time gorged with gravel, probably because of the sudden bend at this point to the west. The most remarkable

thing about the valley is its depth and the extent of erosion it displays. When, as evidenced by the topography, the glacier lay about Bancroft and Burt the marginal drainage was into the channel of the Des Moines especially by way of the Black Cat, Buffalo Fork and Linder's creek and these tributaries all show the same very marked erosive features. Indeed all the streams that converge immediately north of Algona are more or less deeply eroded and the drainage of this part of the county, south of a line passing through Lone Rock, is proportionally good. The stream channels cut thus deep in the prairie are here and there quite heavily bordered by native woods and the natural scenery is often beautiful.

The streams in the northern half of Kossuth county are all simply sloughs. Mud creek, the longest of them is well named: for the greater part of its course through several townships it has no eroded channel and waits the tardy aid of a county ditch. The Blue Earth river flowing north carries a strong current and seems to be the principal outlet of Union Slough and probably carries away most of the water from the public ditch which enters the upper end of the slough, draining Ledyard township.

The Iowa river is especially interesting because heading in the territory before us and so illustrating the beginnings of a characteristic or typical prairie stream.

The Iowa river drains the eastern half of Hancock county and flows southward in two perennial forks, both determined in course by the topography of the moraine, both, but especially the western, primarily a drainage channel for the inner margin of the Altamont. Neither gives evidence anywhere within our limits of any extended erosive power. Where the valley is large or wide its width is referable to the original position of the knobs or hills more than to any carving done by the stream. The east fork of the Iowa river takes origin in a series of marshes occupying the central sections of Madison township, Hancock county. Some of these swamps are within less than half a mile of the course of the west fork in this locality. Having gathered the waters of most of the sloughs in Madison township and the north part of Garfield township, winding about amid the morainic ridges and ever escaping southward where the hills have

left a convenient gap, the stream tends at length almost directly southward along the east line of Garfield township and so continues for some eighteen or twenty miles, leaving the county five miles from the southeast corner. The stream receives its principal tributaries from the high flat prairies of Ell and Avery townships, the moraine on the east side of the river holding a respectful distance, four or five miles or more away; on the east the valley is limited by morainic swells and ridges all the way; these are especially prominent in the vicinity of Goodell and Klemme. At the latter point the stream has cut through an eastward projecting spur. Near the old town of Amsterdam in Avery township the river has a wide alluvial sandy flood plain, but it emerges from the county with only a narrow slightly eroded valley. The west fork of the river in its rise and progress is more remarkable still. Crystal lake may be called the head of the Iowa river. Its outlet flows east or northeast and passing through a gap in the morainic ridge just south of school house number one in Crystal township, helped by a ditch, the stream turns southeast into Madison. It seems that the waters of Edwards lake at time of overflow, a rare occasion, also seek the same channel, although it is possible that in high water the lake might drain equally well into a marsh to the east. This latter has been ditched into communication with a branch of Lime creek, care being taken to avoid the upper ramifications of the east fork of the river. Such are the difficulties under which one of the principal rivers of Iowa is determined in its first outgoing.

Once started the river streams on from one swamp to another avoiding many and finally, as the east fork, on the bounds of Crystal township turns directly south passing Eagle lake one-half mile to the west, but draining it only indirectly and in most circuitous fashion, then on south, almost directly south, limited by moraines now on this side now on that but forming no valley for itself until it cuts through the moraine to the east at last in Winfield township and thenceforth occupies a channel distinctly erosional until it leaves the county within about three miles of the point of emergence of the east fork. The streams are thus seen to be nearly parallel. Their direction and proximity are equally remarkable. They are more than once within three or

four miles of each other. The phenomenon is explained only when we study the topography which they have not caused but by which they are from first to last conditioned. For this reason these streams, although perennial and of considerable importance are less efficient in conveying away the surplus water of the fields. Only at the last have the currents sufficient fall and force to excavate a channel. Hence only in the southern townships of the county are the valleys really serviceable. Erosion has nowhere affected the secondary streams, and ditches are the order of the day.

Another prairie stream which must be mentioned here is the Boone river. This also takes its rise in Hancock county and is likewise of minimum service as a drainage channel. As above remarked the general slope of the country is south and the Boone in most of its course simply creeps aimlessly about upon the surface. Erosion appears in the vicinity of Corwith and thence south, but the main stream and all its tributaries are simply wide low swales or depressions over which the waters spread in times of flood, but, except as aided by human device, produced no erosive change whatever. Paradoxical as it may seem, the valley of the Boone in Hancock county is an almost level plain; a depression unperceived by him who passes over it.

Lime creek is the third principal drainage channel of the territory now examined. This water rises in Minnesota and enters Winnebago county as a considerable stream about three miles east of the northeast corner of Norway township. The general course for many miles is almost directly south, the westing being only about four miles in Winnebago county. This stream also represents the original drainage of the inner margin of the Altamont. The whole of the three eastern townships of this county is morainic. In fact these townships have practically no drainage at all, for there are, strange enough, no tributaries to Lime creek from the east. Beaver creek in the southeast is of value to Mount Valley township; but although the whole country is hilly it is without natural drainage to a very large extent. On the other hand a considerable but very imperfect drainage enters Lime creek from the west. The county ditch following sloughs and swamps, some in natural connection and some not, now drains

all of Newton township, drains Lake Harmon in Logan township and even the east side of King township. The channel of Lime creek is generally wide but uneven, little eroded above Forest City. At Forest City the erosion is very marked. Forest City occupies part of a morainic ridge some seventy feet above the flood plain of the creek, so that the valley here is not only deep but remarkably narrow. There is every reason to believe that the creek has since the retreat of the ice cut through the moraine, which is indeed part of the Pilot Knob system, and so found its way into the much broader valley immidiately to the south. This valley, however, leads east; there are in places considerable flood plains and here and there a considerable deposit of gravel; but in general in Hancock county the creek simply winds about among the morainic hills showing only here and there evidence of efficient erosion. Immediately northwest of Forest City is a sandy plain including a number of the south-central sections of Forest township. This with the rather wide alluvial bottom land or flood plain of the creek from Leland south all tends to confirm our conclusion that at Forest City the narrow valley has only recently, as such things are esteemed, been cut down and through. If one examines the map and the general trend of the moraines there sketched, together with the course of the Lime creek as far as Forest City and that of the east fork of the Iowa, he can hardly resist the conclusion that these streams might really have been one but for the curious intervention of the successive morainic ridges which first damned up Lime creek altogether and then shunted it away off eastward and northeastward ere ever it made escape southward and eastward in accord with the general slope characteristic of this part of Iowa, and the general trend of Iowa streams.

All the streams here described are remarkable in that they take origin in simply wide-extended meadows, great marshes on which the water is generally nowhere deep enough to prevent luxuriant growth of sedgy vegetation, but which seeps away with such slowness as to become in fact a perennial fountain. The effect of man's interference has been in many cases,—by no means yet in all,—to hasten by ditching the escape of the marsh water and at length of the storm water, so that such rivers as the

Iowa are likely more and more to become tenuous and uncertain in dry weather, more and more impetuous; sudden, erosive torrents in time of protracted rain.

GEOLOGICAL FORMATIONS.

GENERAL DESCRIPTION.

The geological formations represented in these three counties are very few; in fact, but two, and these are no more than two superimposed sheets of till or drift with no indurated rocky strata exposed or even discoverable, except by the well-digger's drill, in the whole area. The geology is almost wholly surface geology and apart from the topography just described offers few themes for present discussion. There are no quarries, save the scattered bowlders of the prairie; sometimes so large that a single one constitutes for a time a local quarry, sometimes so abundant that a single farm may furnish building stone for the neighborhood and to spare. Here are named the only geological formations recognized:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Glacial.	Wisconsin. Iowan. (?) Kansan.

The Pleistocene System.

KANSAN DRIFT.

The Kansan drift is the name applied to the vast body of glacial detritus spread over nearly the whole area of Iowa and constituting still the superficial deposit of the larger portion of the State's area. Older than the other generally recognized drift sheets it lies beneath these and so, as in our present field is only here and there exposed, although everywhere discoverable. The farmer who sinks a well, or sometimes even the man who excavates a cellar, the road-maker who cuts the hills, the railway engineer who empties a pocket of gravel,—anyone who for any reason cuts through the common country clay is sure to encounter sooner or later what he calls a hard-pan of blue clay. This ex-

perience is so general that it is everywhere understood. The blue clay is a recognized sub-stratum of which everybody is sure, the only question being as to relative depth or position and its thickness. The student of surface deposits recognizes in this omnipresent sheet of blue clay a member of the Kansan drift. Whatever may be above it or below it this much over the whole state, with few minor exceptions, is fixed and constant. Now in the area here described the blue clay, so far as discovered, comes naturally nowhere to the surface. It is probably very near the surface in many places, covered by the black soil only; but its proximity to the surface even where so reported, could not be confirmed. The Kansan clay has however been uncovered in places not a few by artificial means and sometimes by erosion. Besides, the bottom of Union Slough and the beds of many of the lakes and sloughs are said to be blue clay. The bottom of the Irvington gravel pit seems to be blue clay, and road cuttings between Algona and Irvington, along the river, reveal the same peculiar, easily identified formation. Along the road that leads up from the river southwest in section 10 a peculiar jointed clay may be observed which represents an oxidized upper portion of this same blue clay horizon. The experienced traveller along the highway will catch many such glimpses, especially after heavy rains when erosion is everywhere unusually fresh and clean. It may be worthy of record that for such observation the summer of 1902 gave exceptional opportunity. But beyond all surface exposures, the record of every deep well in the whole country establishes the presence of the Kansan drift as the universal subjacent stratum over our entire area. Just above this hard-pan of blue clay there is often found in other parts of Iowa a deposit of hard compact brown or reddish gravel, and traces of this are also not lacking in the surface exposures referred to along the Des Moines river.

It was to be expected that traces of the Iowan drift had been discoverable here. This deposit in Cerro Gordo county and all the country east constitutes the surface and lies directly upon the Kansan or upon the country rock. It seems, however, that in this neighborhood the Iowan deposits are very thin, very scanty, represented in many places, as it appears, by trains of

bowlders only.* Besides the opportunities for observation, for tracing lines of contact in materials so easily displaced are not many. The country as already shown is flat save as covered by piles of the later drift, conditions entirely unfavorable to stratigraphic observation. It is difficult to say how much farther than present known limits the Iowan may have extended westward; its western moraine has been obliterated in this latitude, did such ever exist; nevertheless it is to be hoped that somewhere within the limits of the counties now before us, possibly in Hancock or Winnebago counties, probably not in Kossuth, which is too far west, some section more fortunate may one day reveal the sequence of all the Pleistocene deposits that here properly belong or may in good reason be assumed. There is evidence also in the report of well-diggers for this region, of the existence of still other, older, Pleistocene deposits beneath the Kansan. Everywhere come the usual reports of the finding of muck, twigs, sticks, etc., under the blue clay, with bad water from the black horizon. All this indicates, of course, that this blue clay bed covers an older surface, a surface once green with vegetation as is the present, though with a somewhat different vegetation as the twigs and sticks would show. Besides, after passing the blue clay the drill often goes through gravel, and other drift material for considerable distances before reaching limestone. Thus at Lake Mills the town well showed some twenty-five or thirty feet of such material, other wells are reported as showing even more. That is to say there is at least one other drift sheet under that here described as Kansan, but we have not yet sufficient data for its delimitation or definition.

In the same way in which we learn of this formation we come to a knowledge of the rocky floor which at greater or less depth underlies all this great body of drift gravels and sand and clay. The limestone that crops out in Cerro Gordo and Humboldt counties may guide us somewhat in determining the foundation limestones next the drift in Hancock and Kossuth. They represent possibly the Kinderhook stage of the Lower Carboniferous, or the Lime Creek stage of the Devonian, on the south, with the Cedar Valley stage of the same system in the north, especially in north-

*See, of the present series, Vol. VII, pp. 174-5.

ern Hancock and Winnebago county.* The limestone occurs at no great depth in any part of our field; thus at Lake Mills the depth is reported one hundred feet; at Thompson, nearly west, one hundred and eighty feet; at Germania, directly west of Thompson, only seventy feet. At Lone Rock and in that vicinity the limestone lies at from one hundred to one hundred and twenty feet beneath the surface; at Garner, at one hundred and ten to one hundred and twenty; at Britt, one hundred and twenty-five feet; at Algona, two hundred and thirty feet is the report. If this is true the well must have struck some earlier valley or depression, doubtless the earlier channel of the Des Moines. At West Bend, west side of Kossuth county, one hundred and sixty feet is the distance to the limestone. This reveals a remarkable uniformity in the rocky floor on which the drift has been in one deposit after another gradually laid down.

THE WISCONSIN DRIFT.

Without exception, so far as now known the entire surface of Winnebago, Hancock and Kossuth counties is covered by the deposit known in these reports as the Wisconsin drift. Often described in these pages it needs small discussion here. Where exposed by erosion or artificial cuttings it is the same whitish, sticky, pebbly calcareous mixture that we find everywhere as subsoil in all the northwest prairie. In this drift are abounding bowlders, none very large, predominantly of the type intersected by veins of trap and hence where weathered liable to assume fantastic shapes.† (Fig. 18). Occasionally the typical Wisconsin bowlder clay gives place to piles and beds of sand or gravel but this is unusual. Even Pilot Knob piled high as it is, appears to be made up throughout of naught but pebbly drift. The rains of centuries have washed, or course, all the finer earth from the summit of the hill and it now appears bare and gravel-capped, but the gravel is surely superficial only. On the other hand a mound one hundred feet lower exhibits on its western face a gravel pocket of considerable size now used as a source of road-material. Other rocky points appear here and there, as, for ex-

*See, of this series, Vol. IX, p. 122, and Vol. VII, p. 144, *et seq.*

†In Avery township on the farm of Emily Griggs a collection of these peculiar Wisconsin bowlders has been assembled and the stones have been placed in various fanciful postures to which peculiar erosion well adapts them.

FIG. 18. Bowlders liable to assume fantastic shapes.

ample, in sections 1 and 2 of King township, Winnebago county, but even the so-called "hog's back" in Norway township of the same county, a peculiar ridge, some twenty-five or forty feet above the general level, a mile or more in length and in places no more than a rod wide, is probably Wisconsin clay throughout. In the neighborhood of all the lakes there are banks and beds of sand affording not infrequently the luxury of a sandy beach; but such sand is often the result of a re-assortment of materials by the waters of the lake; the finer silt has been removed, the sand remaining on the wave-washed shore.

The Wisconsin Gravels—Under this caption may be discussed the few gravel deposits in the present area which seem to be due to the excessive wash incident to the melting and final disappearance of the assumed Wisconsin glacier. There are few or no such deposits along the Boone river, Prairie creek or the forks of the Iowa. Such as we have are to be seen along the Des Moines river below Algona. This indicates that the rapid drainage of the disappearing ice found principal exit by way of the

larger river. From a point about two miles south of Algona on to the limits of Kossuth county the Des Moines channel has been choked with gravel. This is especially notable at Irvington where from a bed of such material the Northwestern railway has taken out hundreds of carloads of gravel ballast. At Irvington the river shifts abruptly west for a couple of miles and the northern bank is an immense gravel train. So at Lime creek in Ellington township of Hancock county; the drainage before it cut through at Forest City must have gone over the ridge and found ready to hand south of Pilot Knob a considerable valley which it proceeded to fill up with gravel. The Burlington and Cedar Rapids railway has availed itself of part of this overwash found in the gravel-pit some two miles south of Forest City. In sections 15, 16 and 17 of Ellington township gravel trains are conspicuous along the north side of the creek. A well sunk on the Beadle farm, section 16, shows that the gravel is there more than forty feet in depth. These gravels are all referred to the close of the Wisconsin period. They are, when seen in section, fresh-looking, only slightly coherent or compacted, non-ferruginous; they contain many rotten bowlders, but these chiefly of the coarse-grained type whose elements were originally less intimately united. Water-laid beds of sand with abundant cross-bedding alternate with the layers of coarser gravel.

Finally, it is interesting in this connection to note the varying thickness of the surface drift. No doubt if all the data were in it would easily appear that the Wisconsin clay here as farther south, is relatively very thin; simply a veneer. No wonder old channels are sometimes all unfilled. In Kossuth county the blue clay is encountered often at a depth of five or six feet. About Bancroft the pebbly clay is said to be from ten to fifteen feet in thickness. In eastern Winnebago from six to thirty feet and so for other localities. At Algona the reported thickness is ten feet, along the river it is certainly more; at Whittemore ten to fifteen feet is the thickness reported. The knobs and mounds previously described where the deposit would seem much thicker are simply material undistributed resting on the old topography which, where the distribution of Wisconsin material has been accomplished, is often but slightly changed by the presence of this lat-

est surface sheet. Furthermore, if the testimony of farmers is reliable, and it probably is, there are as already stated many places where blue clay lies immediately under the black surface soil. In these places the newer drift is of course lacking altogether. These localities are generally low, and represent, probably, pre-Wisconsin depressions.

Soils.

The soils of these counties are in all respects similar to those of the neighboring counties west. Over all is the same rich mantle of black surface soil of apparently inexhaustible fertility. In the region affected by the knobby drift as described in the pages preceding, there are hilltops from which the black soil has been largely removed by erosion. These pass for gravel hilltops; but in the great majority of cases there is really very little gravel or sand. Even Pilot Knob, although at the summit covered with small stones and pebbles is not a gravel mound; the real gravel deposit appears on the hill immediately west. Nevertheless there is some difference in the soils of these different counties when studied in detail. We have the soil of the upland and the soil of the plain, both resting on a subsoil of pebbly clay. This includes by far the greater part of the entire area under consideration. In the lowlands these black soils are often very deep; reported sometimes as much as four feet; on the hillsides much thinner, as would naturally be the case, and often more serviceable for immediate cultivation since the flats contain at times considerable peat, or at least soil in which organic matter has only partially decayed. This seems to be nearly everywhere the situation where marshes of considerable extent have been lately drained. Such soils are really suffering from excess of richness, and improve rapidly under the ventilation they receive in cultivation. Sometimes these lowland soils lie immediately upon the blue clay and these suffer from lack of subsoil drainage but these cases are few. In not a few cases in the knobby drift region there is considerable sand in the subsoil and sometimes at the surface. This is noticeable in the eastern townships of Winnebago and Hancock counties particularly. There is a similar condition along the east side of Union slough in Kossuth county.

Where the sand is not in excess the soils are improved by its presence. In German township of Hancock county are some of the finest farms to be seen anywhere and the proportion of sand is much greater than in most other localities.

The farms along Lime creek have not infrequently a sand or gravel subsoil; along thc Des Moines south of Irvington there is some alluvial soil resting on beds of gravel, and in a few other localities a gravel subsoil has been reported or observed, but in general the soils of these counties are very uniform, rich, and unfailingly productive. They are almost always so level that they will never lose by erosion, and as the drainage of the county becomes more and more perfect the whole country will gradually assume the appearance of a well tilled garden.

ECONOMIC PRODUCTS.

There is no petroleum, no coal, no lime rock in these counties. The limestone is buried under drift and from forty to one hundred and twenty feet below the surface; no coal has been reported by those who year by year send down their drills in every part of the country, and petroleum has seemingly not yet been thought of. The discovery of either coal or petroleum in this part of Iowa is, as we know, unlikely; the whole region is north of the known limits of the Iowa coal field.

Notwithstanding the lack of stratified rock in place the country is liberally supplied with building rock, suitable for foundation purposes, at least, in form of surface bowlders. These when large are broken up in the field. In any case the granite is sold by the cord. Fourteen tons are reckoned a cord, and in Kossuth county the price is quoted at ten dollars per cord. The farmer commonly finds on his own premises sufficient stone for all his needs. Sometimes, indeed, the bowlders are far too numerous. Hundreds lie along the fence rows. One farmer reported three hundred on forty acres, all taken to the fence-line in a single season.

There are for present report no exposures of valuable clays. Nevertheless, the manufacture of brick and tile has in many places been attempted. Mr. Pitkin has spent large sums of money and much time near Forest City in an attempt to manufacture

brick and tile. The clay is said to cap blue clay. The worked bed is five or six feet thick free from pebbles or other objectionable features and the product as shown by the specimens on the ground is certainly good; better than any so far noted on the Wisconsin drift region. Nevertheless, for some reason the enterprise seems to have been abandoned. The deposit is apparently an aqueous sediment, resembles loess. At Klemme, or near it, tile of fair quality is manufactured in limited amount. Near the river at Algona brick is manufactured from Wisconsin clay rather unusually free from pebbles. The brick and tile, however, show the usual fault; the lime pebbles that are present slack after burning and so make trouble. The brick are very soft, suitable it is said for inside work only.

At Britt, the Interstate Drainage Company began operations about July 15, 1902, and are even now (October) enlarging the plant. They have burned about 50,000 brick of fair quality and 60,000 tile. The demand, so far, is far in excess of the supply. The material is apparently Wisconsin clay of superior quality. The fuel is coal.

The gravel which occurs in great abundance here and there should not be overlooked in a resume such as this. This gravel makes the best of roads. In many parts of northern Iowa its value is appreciated to such extent that miles of country roads are paved with it. Unfortunately for road-making, gravel though widely is not evenly distributed in nature. It occurs sometimes where not needed, and again cannot be procured conveniently where needed most. All the marshes of Kossuth and Hancock counties have been bridged by so called grades; these are often of gravel and excellent. They must be made of something other than ordinary surface soil if they are to be permanent.

Water Supply.

The running waters of the counties here described are of considerable value. In Kossuth county particularly, good perennial streams are well distributed. The Des Moines river waters a large section of the country while its several tributaries, the Buffalo, Black Cat, Plum creek and Lott's creek are far-reaching

and presumably perennial streams. In Winnebago county Lime creek is the only stream of value or importance. It is probable that the county ditch may be of service not only in draining wide-extended marshes but also as a water supply for many farms in the township by which it passes. In Hancock county we have the two branches of the Iowa river, both valuable streams especially in the southern townships. The Boone river also affords water for stock in the southwest part of this meadow county. There are besides in all these counties abundant pools and small lakes that are often serviceable in the care of stock. Some have been artificially deepened and made permanent.

By far the greater number of farms have deep wells and wind-pumps, with reservoirs of various sorts. Water is obtainable at varying depths. Many of the wells seem to yield abundant water above the blue clay at the surprisingly shallow depth of fifteen to twenty feet. In Mount Valley township wells eighty feet deep have water within ten feet of the surface. Such go through the blue clay but not to rock. Forest City has a well located near Lime creek, north of the city and three hundred and two feet deep; the well is flowing at the level of the creek or a few feet higher. In the eastern part of our territory rock is reached at about 120 to 130 feet, occasionally much less, and the wells enter the rock for varying depths. In Kossuth county, northern half, the rock seems to be not more than seventy-five to one hundred feet below the surface and at Germania a flowing well is found only sixty feet deep. Other flowing wells are found about Ledyard and indeed on all the farms from Germania north and west. Flowing wells are common also along the Boone valley in Hancock county. So far as could be learned they are simply drift artesian wells; they do not in the cases reported reach the underlying limestone of the country at all and owe their peculiarity to the local topography, the intake being the morainic fields of southern Minnesota, of Winnebago and Kossuth or possibly of northern Hancock county. At Garner the town well is one hundred and twenty feet deep; about twenty feet to blue clay which is here some forty feet in thickness; "gravel and rock" make up the remaining sixty feet. The well at the Milwaukee railway station at Britt has been already quoted in these

reports.* This is over five hundred feet deep, but the town well a mile away finds abundant water at one hundred and twenty-five feet, ten of which are in limestone.

In general over the whole area here described water is reached at or near the surface of the limestone. The average depth of wells is not far from one hundred feet and the supply at this depth for all ordinary purposes is apparently inexhaustible. The water is generally reported good. Less complaint than usual is heard of bad water under the blue clay caused by slowly decomposing organic stuff. The deeper well at Britt, mentioned above, affords water which contains in solution an inconvenient amount of solids which tend to form incrustations and so choke up pipes.

ACKNOWLEDGMENTS.

In the prosecution of the work here recorded the author acknowledges his obligations to many citizens of the region, farmers especially, who were ever ready to aid in every possible way. To Supt. A. M. Deyoe, Mr. J. A. Treganza, Hon. Eugene Secor the Survey is indebted for special favors. In the preparation of the list of native trees following, the author would acknowledge his indebtedness to his colleague, Prof. B. Shimek, who in the interest of the United States Bureau of Forestry has made a special study of this particular part of Iowa.

FORESTRY NOTES FOR KOSSUTH, WINNEBAGO AND HANCOCK COUNTIES.

The forest area in these counties was originally, and has been until recently, rather larger than usual in prairie counties. Especially is this true of Hancock and Winnebago. In the latter the greater part of the eastern townships was originally covered with forest trees and until comparatively recent years the same region has been more densely and extensively occupied by young native forest, the so-called "second-growth." The same thing was true of a large part of Forest township and of Newton township, and there was native wood about Lake Harmon, and perhaps one or two other native groves were known to the pioneer. In Hancock county Ellington township, with the southern slopes

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of Pilot Knob and the banks of Lime creek, were all extensively wooded country and native groves were found all along the Iowa river in Avery township and about Amsterdam. There is still a native grove at Twin lakes and one in section 11 of the township of the same name, and another at Crystal lake. The latter is now in part a park. In Kossuth county the native woods were limited pretty nearly to the valley and flood plain of the Des Moines river, particularly below the point where the tributaries, Black Cat and Plum creek, enter. The list of species represented in these native forest plantations includes the names of nearly all the arboreal forms found in eastern or especially northeastern Iowa. Along the Des Moines about Algona and along Lime creek east of Forest City and especially on Pilot Knob and on its attendant hills genuine forest conditions prevail. Undisturbed by fires the trees make luxuriant growth and add a beauty to these prairie landscapes otherwise unattainable. The presence of Pilot Knob and its wooded sides, seen like a blue wall from all the surrounding country for miles, has to this country and for it a real commercial value, and if the people who are so fortunate as to own farms and homes in the neighborhood of this piece of natural attractiveness are wise they will never suffer its beauty to be destroyed. Steps should be taken to make Pilot Knob with its woods, its lake and its meadows, its exhilarating heights, a park to be for the delight and enjoyment of the people for all time. Algona has also great natural advantages. Her wooded banks and woodland drives along the river and across it, attended by the rich variety of native groves, are certainly surprisingly beautiful and should belong to the city, some of them at least, for the benefit of coming generations.

Tree-planting in these counties has proceeded much as elsewhere for the purposes of shelter and fuel. Every farmer has a grove, and some of these are of fine proportions and show beautiful trees. Here as in other Iowa counties the species planted have been selected as rapidly growing, rather than for value when grown. Nevertheless there are plantations sufficient to show that all sorts of trees common to our northern nurseries may be successfully reared along these northern borders. Mr. Eugene Secor has hundreds of conifers to show how easily the farmers

of this region may provide themselves with timber, even for lumber. The primeval trees in all the forests named have nearly all long since disappeared. They were the product of centuries and were ripe for the harvest. Time has not elapsed for their successors to attain much value; but there is no doubt that the most valuable hard-wood trees of our northern forests will yet again find place upon the hills and by the streams of the counties to which they are native and in which history shows that they find congenial skies and soil. The observed species in the several localities discussed are named in the following list:

Tilia americana L. Linden. Basswood.

The linden is a valuable and beautiful tree not uncommon in all our northern forests. In Iowa the species is usually encountered on the hillside not far above the flood plain of some perennial stream. It is common along the Des Moines about Algona, along Lime creek about Pilot Knob, nor is it lacking to any of the native groves mentioned in the paragraphs immediately preceding. The stooling habit of the tree which often gives us two or three or more distinct trunks from the same stump prevents the otherwise rapid development of a large tree. Nevertheless basswood logs and lumber were familiar to the pioneer, and an occasional trunk two or three feet in thickness is yet to be found in our native woods. The tree grows well when transplanted, is clean and beautiful and forms a dense delightful shade. The bloom in midsummer is pleasantly fragrant, the delight of the bees and the source of our very finest variety of honey.

Celastrus scandens L. Climbing Bittersweet.

This singular forest plant is not infrequent in all the groves of northern Iowa. Its peculiar habit attracts the attention of the woodman who very frequently comes upon a young elm or even hickory entirely smothered, its trunk fairly strangled by the twining coils of its too affectionate neighbor. The effort of the afflicted tree to send down nutrition to its roots results sometimes in a curious swelling ridge which like a giant corkscrew affects the tree-trunk from bottom to top and remains a permanent disfigurement even after the assailant has entirely disappeared. Nevertheless the vine is a favorite cover for un-

sightly fences, and is sometimes planted for an arbor. In any situation its bursting, but long enduring, scarlet fruit is one of the cheerful sights of our western autumn.

Ceanothus americanus L. Jersey Tea. Red-root.

This little shrubby bush well deserves attention and preservation on account of its abundant and handsome bloom. It is found on the borders of dry woodlands everywhere and in summer contributes its share to the beauty of Pilot Knob. As an ornamental shrub certainly one of the finest native to our prairie state and worth a dozen imported but less hardy species.

Vitis riparia Michx. Wild grape.

This is the familiar wild grape of all the west. Native by every stream, climbing in every thicket, it quickly avails itself of the shelter afforded by planted groves and may be found on many a farm removed from its original habitat. The fruit, ripe after frost, is still much sought by those with whom still lingers the clean pure taste of the pioneer, the bloom is fragrant to an unusual degree, and hardy vigorous growth commends it as a valuable climbing shrub eminently fitted for the covering of objects unsightly in town or field.

Ampelopsis quinquefolia Michx. Five-leaved Ivy. Virginia Creeper.

The Virginia creeper is a universal favorite as a cover for the masonry of walls, for fences, etc. It has a great advantage over the grape in that its tendrils adapt themselves to various supports. They know well the roughened or weathered surface of various objects and spread adhering disks against the face of a tree stump or quarry wall. Hence the name five-leaved ivy. The plant very well supplies in this country the place of the English ivy. It will cover a stone building from top to bottom and adheres well to brick if not too much exposed to our burning summer sun. Five-leaved ivy bears no relation to the so-called "Poison ivy," is by no means poisonous. The foliage in autmun turns brilliant red, conspicuous in the autumn thicket. The fruit resembles that of the grape, but the cluster is open and the dark blue berries are few.

Acer saccharinum L. Soft Maple. White Maple.

The soft maple is the most familiar tree in Iowa. Universally planted on every prairie farm it is at once ornament and shelter and has transformed the landscape of the State. The tree is of surprisingly rapid growth, its wood makes excellent fuel and a quality of lumber much esteemed, especially in furniture-making. On the other hand the wood of the soft maple is brittle and in our latitude and climate the long branches not infrequently fall a prey to the sweeping wind or the gusts of summer storms. This is *A. dasycarpum* Ehr. of the books.

A. saccharum L. Sugar Maple. Hard Maple.

In this part of Iowa the sugar maple is rare. It was observed and noted in Forest township, Winnebago county only. The tree probably occurs in other places along Lime creek. It was not discovered in Hancock county nor in the valley of the Des Moines although to have been expected. The species is too well known to require much comment. It grows much more slowly than its relative the soft maple, but makes much better wood. When planted as an ornamental or shade tree the drought of an ordinary Iowa summer destroys its upper twigs and branches, so that all such trees sooner or later disappoint us, dying at the top. It seems probable that in any situation trees grown from seed do better than those whose roots have been disturbed and injured in the process of transplanting. In Iowa there were once large trees of this species, even groves of them, "sugar orchards," but these were uniformly found by rocky perennial streams, and in the shelter of other forest trees where the drought was less severe. This tree is called *A. saccharinum* L. in the more familiar literature of this subject.

Acer negundo L. Ash-leaved Maple. Box Elder.

The box elder is our universal tree. Native in all the eastern portion of the State it is now planted and naturalized in every county. As a shelter tree it rivals the willow and soft maple, especially in rapid growth, and makes a denser shade than either. Its habit is however very different from that of other maples. It tends to make crooked branches and a round dense head. Even in thick groves the trunk may rarely be induced to grow straight.

The tree is nevertheless valuable in every way, for shade, shelter, and fuel.

Rhus typhina L. Velvet Sumac. Staghorn Sumac.

A beautiful shrub is this; sometimes rising to the stature of a small tree, twenty to twenty-five feet in height; rare in northern Iowa. The only specimens noted were in the vicinity of Lake Mills, Winnebago county. Here it occurs commonly by the roadside. It is a most handsome ornamental hardy plant. It tends to form a thicket but is easily kept in check. The curious "velvet" of the young shoots and branches is unique in our forests; the leaves are soft and of delicate tints of green, changing in autumn; the flower clusters are large and showy and the fruit crimson and brilliant. We have nothing better that will endure our climate, probably nothing as good. It is not poisonous, as some are wont to believe, although the fruit is inedible, except by birds, and the peculiar resin of the branches protects the shrubs generally from cattle and horses.

The species ranges along our northern border and in eastern Iowa has been noted as far south as Monticello in Jones county.

Rhus glabra. Sumac. Smooth Sumac.

This is the species commonb throughout the State. Even in prairie counties where natural groves are none or few, the traveller often encounters on some dry hillside a plantation of sumac bushes, sometimes no more than one foot high. On the other hand in the eastern counties the sumac is sometimes a small tree fifteen or twenty feet high. Like the preceding it is one of our own ornamental shrubs and deserves well of every Iowan.

Rhus toxicodendron L. Poison Ivy; Three-leaved Ivy; Poison-vine; Poison Oak; Poison Sumac.

Resembling the preceding in none of its more obvious characters the poison sumac is yet able to lend its own ill repute to all other members of the family. This plant *is* poisonous, at least for many people though not for all. It is sometimes confused with the Virginia Creeper, because like that species it sometimes ascends tall trees, rooting fast to the bark of its host. In Iowa the *three-leaved* foliage is a sure distinction in the growing

season; later the *white dry fruit* will readily separate it not only from other species of sumac, but also from the purple fruited innocent Ampelopsis.

Robinia pseudacacia L. Locust. Black Locust.

Probably indigenous to southeastern Iowa, the locust tree has been very widely planted. For some time less popular because of the depredations of the locust-borer, it is now coming again into favor, being less afflicted. One of our most valuable hard-wood trees; well worth planting for all purposes. Its flowers are beautiful and odorous; its foliage handsome and its wood heavy, strong, of unusual durability when in contact with the soil, hence of highest value for posts.

Spiræa salicifolia L. Wild Meadowsweet.

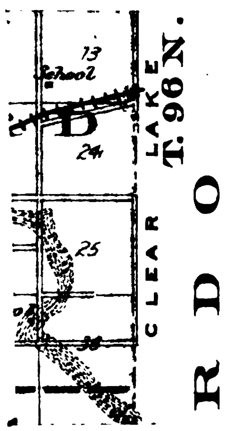
This is a beautiful little shrub with wand-like stems and branches tipped in summer with abundant, spicate, snowy bloom. Common in moist shades, on the flanks of Pilot Knob.

Pyrus iowensis Wood. Crab-apple. Wild Crab.

The crab-tree is common over all the prairie country forming small thickets around the borders of native groves and even on cool hillsides where there are no other forest trees. Its beautiful odorous bloom, the very glory of our early summer, should render this tree a favorite with our whole people and save it from threatened destruction. The agents of the nurseries offer our Iowa farmers long lists of cultivated and imported novelties in the way of flowering shrubs, but not one of them all will for a moment compare with the modest splendor of our Iowa crab, which everybody may have for the planting. It will bear transplanting and grow anywhere.

Cratægus mollis T. and G.; *C. crus-galli* L.; *C. punctata* Jacq.; *C. tomentosa* L. Hawthorn; White thorn; Thorn-apple.

These are first cousins of the crab apple, often, indeed generally, growing with the more familiar species, especially in wood borders or where the forest meets the prairie. Common on Pilot Knob, along Lime creek, and in the groves of Hancock county. Their white flowers contrast pleasantly with the rosy infloresence of the crab, although some are inclined to be mal-



COUNTY
IOWA.

BY
T. H. MACBRIDE
1903.

odorous. The first species is our favorite red haw whose large scarlet apples enrich the fence rows in autumn where the zeal of the road commissioner has not yet found the tree, or the barbarous vandalism of the "line-men" has not yet mutilated and destroyed it.

Amelanchier rotundifolia T. and G. Shad-bush; Service-berry; June-berry.

Recognizable on all our northern country by its fine snow-white blossoms covering the bush or tree in early spring. It blooms before the wild plum, before the leaves are out on anything—save perhaps the vanguard willows,—and marks the whole hillside with its white banners signalling the on-coming of the spring. The fruit is small but edible and in favor with many people so that the tree is often cultivated in country gardens. In habit and foliage variable, there is after all perhaps but a single species, the old *A. canadensis* L of which our round-leaved forms are but the western variety. Along the banks of the Des Moines; on Pilot Knob.

Cornus circinata L'Her; *C. paniculata* L'Her. Cornel-bush; Dogwood.

These are handsome ornamental shrubs. They bear white flat clusters of flowers in early summer and showy, round or flattened, berries in fall; the fruit in the first named blue, in the second white. *C. circinata* endures dry rocky places, even clings to rocky ledges; *C. paniculata* loves the river brink. Found n the thickets along wooded banks in all three counties.

Sambucus canadensis L. Elder-bush. Elder-berry.

The elder-berry is a plant everywhere familiar, often planted in gardens for the sake of its fruit, but now springing up as if native in the rich soil of farm-land and meadow. The abundant black-purple fruit is esteemed as fruit, and is certainly valuable as food for birds.

Viburnum lentago L.; V. *prunifolium* L.; V. *dentatum* L. Sheep-berry; Black haw; Arrow-wood.

Of the three Viburnums in this part of Iowa the first and last as here named are found in wet places or by streams; the

black haw is a small slender tree everywhere in native groves. *V. dentatum* on Pilot Knob only.

Symphoricarpus occidentalis Hook. Wolf-berry.

A handsome shrub is this, native to all the northern counties; abundant about the margins of the groves and so suggesting its proper use in plantations. The elegant little flowers are showy even in the flowery month of June, and the white fruit is in pleasing contrast to the dull tints of the autumn field.

Cephalanthus occidentalis L. Button-bush.

A common shrub in wet places on Pilot Knob; with handsome flowers, in its favorite habitat, but of little general use.

Fraxinus americana L. White Ash.

The ash is a tree of wide range and of universal usefulness. Its wood is excellent for lumber and makes fine fuel. As a shade tree it is clean and beautiful and of reasonably rapid growth. No other tree except the cottonwood and the maple is so extensively planted on prairie farms; nevertheless its value is hardly yet appreciated.

Fraxinus viridis Michx. Green Ash.

This species is not rare along wooded water courses and differs decidedly from the commonly planted species. It is a small, irregularly branched, but vigorous tree, valuable only for the excellent fuel it affords.

Ulmus americana L. American Elm. White Elm.

The white elm is the street-tree of North America. For planting in rows along our village and city streets nothing can match this. The tree is hardy, enduring all sorts of soil and much mistreatment; it grows rapidly and in selected individuals with a symmetry unequalled. Nor only along the highway and street is the elm a thing of beauty; out in the open field or by the prairie stream a single lone elm may often be noticed whose rich umbrageous foliage in summer, and elegant plumy outline in winter, are simply the crowing beauty of the landscape.

The elm is a rapid grower, makes first class lumber for many uses about the farm, and is valuable at last in no small degree as a source of excellent fuel.

Ulmus fulva Michx. Red Elm. Slippery Elm.

The slippery elm occures rarely in the groves of the counties we describe. It is a much less valuable tree than the preceding, although its wood is tough, unsplittable, highly prized for some purposes. The tree is easily distinguished by its extremely harsh, large and rough-surfaced leaves, the stiff rigid branching, and the large- clustered, almost orbicular, rough and venulose fruit.

Celtis occidentalis L. Hackberry.

Fine specimens of this tree were noticed near the old town of Amsterdam, and others in Winnebago county. It is indigenous to our northern counties generally and a delightful tree. It grows more slowly than its cousin, the elm, but makes a much denser shade. The top when left to itself is shapely, the foliage pale green. There is no finer ornamental tree and while its wood is less desirable for lumber it makes the best of fuel.

Juglans nigra L. Black Walnut. Walnut.

This is doubtless, commercially considered, the most valuable species in the whole list. Native to eastern Iowa, it grows well in stream valleys and on prairie plantations as far as the Missouri river. The walnut grove at Whiting in Monona county is famous the country over and there is another in Sac almost as fine. These are both the result of careful planting. In Hancock county there are fine thrifty trees in the groves around the old court-house at Concord. But the species is also represented by native trees at Amsterdam and on the land of Mr. Hathaway in Twin Lakes township. The pioneers seem to have found elegant walnut trees in Wnnebago county and there is still near Forest City, a walnut stump in witness more than four feet across the top. There is therefore no reason why farmers in these counties may not raise walnut timber. The crop is somewhat slow, but if cared for is much more rapid than some people suppose. There are many native walnuts along the Des Moines in Kossuth county but the larger trees have been long since cut away.

Juglans cinerea L. Butter-nut. White Walnut.

The butter-nut was noted in eastern Hancock and in Winnebago. This must be near the western limit of the species in this latitude. Not without value, the tree is nevertheless nothing like so worthy of cultivation as is the walnut. It is by nature a smaller form and although furnishing a fine-grained lumber has not been much in favor with our western people.

Carya alba. Nutt. Hickory; Shell-bark Hickory; Shell-bark.

This valuable species is apparently common in Winnebago county, but less so in the other counties. Only small young trees were observed. The old trees are probably all gone. The wood of the hickory is in great demand in the manufacture of wagons, buggies and other forms of vehicles. A forest of hickory today would be worth a fortune. As fuel the wood is equally famous, and the finest trees of our North American valley forests have been cut down to make winter fires. The hickory grows well and rapidly from seed, and it is to be hoped that within the range of its natural habitat it may be nowhere suffered to become extinct. The bitter nut, *C. amara* Nutt., is also found in our present field; it is a good tree for fuel but in the mill or factory possesses nothing like the value of its associate.

Corylus americana L. Hazel. Hazel-nut.

The hazel nut is so widely known as to require no more than mention here. It is the universal attendant of our native forest, the low, out-creeping border of the woods. It is astonishing how rapidly and easily the hazel extends its beneficent domain. The fruit is disseminated by our familiar birds. Blue-jays will attempt to carry two or three hazel-nuts at a time in their beaks, and will fly with a bunch of the fruit for long distances. In this way people are often surprised to find the hazel springing about the borders of our artificial groves. The birds are the planters and the hazel simply occupies its own.

Ostrya virginica. Willd. Ironwood. Horn-beam.

A valuable though small tree is this, not uncommon. The wood grows rapidly up to a certain age; afterwards very slowly; is tough and exceedingly hard; makes good tool handles and fire-wood.

Quercus. The Oaks.

More than any trees of the forest, the oaks appeal to every lover of the wood. On Pilot Knob five distinct species of oak occur, and three or four in other parts of our area. The universal species is of course the bur-oak, *Q. macrocarpa* Michx. This species occupies the very hardest and most unfavorable rocky or sandy hilltops, remote from all other arboreal vegitation. Next in frequency is the jack-oak, *Q.velutina* Lam., occupying the whole forest area already referred to, the whole Mississippi valley. On the slopes of Pilot Knob beautiful specimens of *Q. scheckii* Britt., the scarlet oak, adorn the roadsides and fields, their thin elegantly cleft leaves shining with unusual lustre in the summer sun. In similar localities and in the valleys of all the wooded streams occurs another common species *Q. rubra,* L. the red oak. The three last named all belong to the black oak series; all have dark-colored, furrowed bark, bristle-tipped leaves and fruit, and acorns that take two years to mature. The bur-oak, on the other hand, belongs to the white oak group. Its leaves have rounded lobes, are never bristly; the bark is pale and often flaky, though in old trees apt to furrow, over certain areas, and the nuts form and mature in a single season. The white oak, *Q. alba* L. is the finest and most valuable oak in our northern woods, and is fortunately not rare in Iowa. The writer noted, however, in the district covered by this report but very few, and these in Forest township of Winnebago county.

All sorts of oaks may be transplanted but they, like other forest species, grow best from seed. Acorns spring up readily if protected from animals and covered lightly with leaves. When cared for they grow with surprising rapidity, easily making two or three feet a year in height. There is no good reason why on the farms of northern Iowa oaks, ash trees, walnuts, pines may not begin to supplant the useful, but less valuable soft maple and box-elder.

Populus tremuloides, Michx. Quaking-asp.

A common little tree in all native groves. Of little value save as light fuel. Its nearest kin, *P. grandidentata* Michx., the large leaved aspen, or simply aspen, is much more valuable. It springs

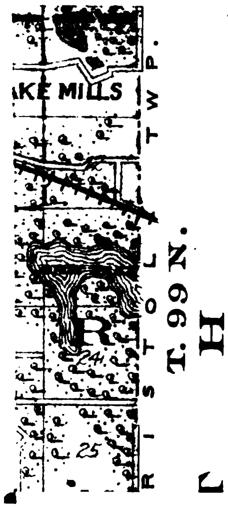
up quickly in clearings, grows in dense hillside groves and in a few years makes fine long straight poles, light and strong for use on the farm. Hundreds of these trees are found on the slopes leading up to Pilot Knob. The cotton-wood, *P. deltoidea* Marsh., has been extensively planted here as in all our western country. The cotton-wood makes good fuel and has been of service as a wind-break. Does not however, make good groves.

Salix species.

Of willows there are many in our region. Prof. Shimek furnishes me the following list: *S. discolor*, Muhl.; *S. amygdaloides* Anders., diamond willow; *S. cordata* Muhl., heart-leaved willow; *S. candida* Willd., hoary willow; *S. humilis* Marsh., prairie willow; *S. petiolaris* Smith, has no common name. In fact, the willows are for our people little distinguished. Most of those here listed are mere shrubs without economic value save as ornamental plants. The first two named are small trees.

Juniperus virginiana, L. Red Cedar.

This is the only representative of the conifers or pine family in this part of Iowa. The white pine seems not to come so far south and west. The little red cedar is said to be still not rare about the shores of Rice lake, Winnebago county and many are reported as taken thence for planting on the farms. All the conifers usually planted in Iowa have been successfully reared by the farmers of the counties here discussed. So much in genuine arboriculture has here been already wisely done that we have high hope for greater success in time to come, when to the other crops making Iowa the land of varied husbandry shall be added a perennial harvest of forest products from trees of all our noblest species.



OF

WINNEBAGO

COUNTY

IOWA.

BY

T. H. MACBRIDE

Geology of Mills and Fremont Counties

BY

J. A. UDDEN.

GEOLOGY OF MILLS AND FREMONT COUNTIES

BY J. A. UDDEN.

CONTENTS.

INTRODUCTION.

CATION AND AREA.

are the two southernmost counties in the issouri river. Together they form a rect- ight sides on the north, east, and south, the Missouri river on the west, extend- forty-one miles from north to south, and nineteen to twenty-six and a half miles y have an area of about 974 square miles, ut 524 square miles and Mills about 450. the meanders of the Missouri the area

RLIER INVESTIGATIONS.

visited these counties in 1866. He was of Iowa, and his observations were pub- Annual Report in 1868, and also in his 1870.*

the Coal Measures of these counties are s Coal Deposits of Iowa.†

on has published a record of the Glenwood and Mr. Seth Dean has secured other data he temperatures of the wells at this place.**

ual Report, State Geologist, 1868, pp. 54-59; C. A. White, Geology of pp. 357-371.

ical Survey, Vol. II, p. 448 and pp. 452 and 453.

logical Survey, Vol. VI, pp. 340-347.

of Iowa Engineer and Surveyors' Society, 1895, pp. 33-39

Finally Prof. J. E. Todd, who for some time resided at Tabor, has made a number of observations on the drift of this region, and many of these are presented in his paper on The Moraines of Southwestern South Dakota and their Attendant Deposits.*

PHYSIOGRAPHY.

TOPOGRAPHY.

The principal topographic features to be noted in these counties are: The upland flats and ridges, the upland slopes, and the lowlands and terraces.

The Upland Flats and Ridges. The uplands consist of an old drift plain, modified by erosion and by the deposition on its surface of a blanket of loess. But little is left of the old surface of the flat drift plain. The only remnants left are some flat strips of land on the highest divides farthest away from the largest streams. These strips are usually less than one-fourth of a mile in width, often much less. The widest flats seen were between the headwaters of Mill creek and Rock creek in Locust Grove township in Fremont county; in the vicinity of the town of Tabor; on the divide between Mud creek and Silver creek southeast of Silver City; on the divides north of Glenwood, north of Emerson and north and south of Hillsdale. The total area of these upland strips do not cover more than at most a few square miles of land in the two counties.

Excepting these flat areas the divides everywhere consist of ridges, more or less convex in cross section. These are broadest farthest away from the principal drainage basins and as we approach the margins of the uplands they become more and more contracted and narrow. In the bluffs of the Missouri they are frequently only three or four feet across, with a steep slope on either side. The average elevation of these summits of the uplands for the two counties is about 1170 feet above sea level, and it varies a hundred feet above and below this figure. The eastern two-thirds of the uplands in this area fall about thirty or fifty feet below the average, while the highest divides approaching the Missouri river bluffs rise above it in places as

*J. E. Todd, Bull. U. S. Geol. Survey, No. 158, pp. 89, 90, etc.

much as ninety feet. From north to south they have a general descent of about a foot and one-third to the mile.

The Upland Slopes. By far the greater area of the uplands is formed of slopes which extend on either side from the creeks and ravines up to the crests of the ridges and flats on the divides. Farthest away from the larger drainage lines these slopes have a gentle grade and even near some of the larger creeks they may be a half mile in length and 100 or 125 feet in height. But near the Missouri bottoms they become more steep and frequently rise at a high angle to 150 or even 200 feet above the bottoms. Along these bluffs they are sometimes too steep to be tilled. Elsewhere they constitute the main farm land in the region. The distance from the foot of the lowest to the top of the highest slopes embraces a vertical range of about 360 feet.

The Lowlands and Terraces.—The principal lowlands are the bottoms along the Missouri river. These vary from one to seven miles in width on the Iowa side of the great river. They have an average elevation of about twenty feet above low water and an average descent to the south of about one and one-third of a foot per mile, their general slope being about the same as that of the uplands. In the reentrant bends of the river bluffs, where the bottoms extend into the uplands, as they do to the southeast of Pacific Junction, north of Thurman, and again south of Knox, they rise as much as thirty or forty feet with a long gentle slope toward the bluffs. Otherwise they present an even plain with a few low tracts marking the former meanders of the river, such as Buckingham lake and Lake Wabonsie.

The lowlands of the West Nishnabotna have a pitch to the south of a little more than three feet per mile and a width increasing from one and three-fourths of a mile near the north boundary of Mills county to three miles in Prairie and Sidney townships in Fremont county. The pitch of the East Nishnabotna bottoms is a little greater, nearly four feet per mile, and their width from bluff to bluff averages about two and three-fourth miles. Near Riverton this valley is abruptly contracted to less than one mile. The valley of the united streams below Riverton in the same way abruptly narrows at the north boundary of Madison township to less than one mile. The cause of

Deposit of mud after a flood on the Nishnabotna bottoms in section 19, Riverton township, Fremont county.

such abrupt changes in the width of these lowlands is a rise of the bed rock which has impeded the erosive work of the streams in widening their flood plains, owing to the greater hardness of the materials encountered.

Other creeks with definite flood plains are as given below:

CREEKS.	AVERAGE WIDTH OF BOTTOMS IN MILES.	SLOPE, FEET PER MILE.
Walnut	.9	6 (estimated)
Silver	.8	5 (estimated)
Keg	.6	7
Indian	.4	10
Mill	.3	10 (estimated)

The bottoms of Silver, Keg, and Mill creeks are all somewhat contracted in their lower course on account of encountering the bed rock, but their change in this respect is not as marked as in the case of the Nishnabotna rivers. Just below Malvern the Silver creek bottoms narrow to only a quarter of a mile for a short distance and at Glenwood, Keg cheek can hardly be said to have a flood plain. The difference is less marked in the width of the flood plain in the upper and the lower course of Mill creek south of Riverton, but in each of these places bed rock is absent above and appears in the beds of the streams at the narrow places.

No notable terraces are to be seen on the flood plain of the Missouri river, but there are a few shelves in the bordering bluffs near the streams which come from the uplands. One of these is seen on the south side of Wabonsie creek, having an elevation of about fifty feet above the bottom, and there are others less distinctly marked in the creeks farther south. On the bottoms of the two Nishnabotna rivers terraces are much more frequent. One which has an elevation of about fifty feet covers the north half of section 26 and the south half of section 23 in Madison township, Fremont county. Another about forty feet high covers the east half of section 6, Tp. 68 N., R. XLI W. For three miles south of Randolph the same bench runs along the east bluff of the valley extending about a mile to the west. Again the same terrace covers about three sections of land west of White Cloud, and there are smaller remnants farther to the north but

on the same side, as in sections 12, 13 and 14 northwest of Hastings, in sections 19 and 20 and in sections 8, 9 and 4 in Tp. 73 N., R. XLI W.

In these counties, as in Pottawattamie*, the bluffs of the Nishnabotna run in a series of loops somewhat less than a mile wide "with their concavities facing the river." The loops are separated by narrow spurs of upland, which intervene and project sometimes half a mile into the valley. It is quite evident that the recesses are due to undercutting by the river and that the curves correspond to the meanders of the stream. As the loops have a radius much greater than the meanders of the present stream it is to be inferred that at the time they were made the river was considerably larger than at present. This may have been coincident with a glacial advance occurring farther north, after the deposition of the drift in this region. Loops of the kind are seen on both sides of the river between Henderson and Hastings to the northwest of Randolph, to the southeast of Sidney, and east of Hamburg.

DRAINAGE.

But little need be said regarding the drainage of the two counties. It differs in no essential from that of the surrounding region. It has reached a stage of high maturity, as may be inferred from the nature of the topography. Drainage by seepage through the porous soil is remarkably efficient everywhere, but during heavy rains there is a prompt run-off from the surface on all slopes. Only a single instance of stagnant drainage on the upland has been noted, and this consists of a small tract on section 36, Tp. 68 N., R. XL W., where a swamp like condtion prevailed at the time of the making of the government surveys. With the general lowering of the level of ground water this has now disappeared. The effectiveness of seep drainage is especially evident on the terraces in the Nishnabotna valley, as to the west of White Cloud, where the surface of the terrace covers an area of three square miles which is perfectly flat and yet remains uninvaded by drainage trenches, although the river, since their making, has had time to remove all but a small fraction of the old flood plain.

*Iowa Geol. Surv., Vol. XI, pp. 205-206.

Deposit of mud and debris after a high flood in a tributary of Keg creek northeast of Glenwood.

Deposit of mud on the bank of the channel of Keg creek, west of Minneola, after high water.

The drainage of the flood plains is in one respect less perfect now than before the prairies were under cultivation. With the general destruction of the native sod the slopes now more promptly shed the surface flow during rains and these easily gather a full load of silty sediment which impedes the run-off in the creeks and fills their channels. The mud can be seen settling on the sides and the bottom of the channel, which thus becomes too small and causes the streams to overflow their banks. The retention of the streams within their banks during floods is thus with every year becoming a more and more serious problem to agriculture. During the summer of 1902 hundreds of acres were flooded and covered with silt on the Missouri and the Nishnabotna bottoms, in places to a depth of as much as three feet. From some measurements which were made on the quantity of sediments carried by Keg creek during a freshet, it was found that the ratio of sedments to the water by weight was 1:44, that is, the water contains about 2.2 per cent of mud.

TABLE OF ELEVATIONS.

LOCATION.	ELEVATION.
Anderson	966*
Bartlett	946
Bluffs east of Bartlett	1190*
Clark	1000*
Emerson	1053
Farragut	961
Glenwood	981
Hamburg	903
Hastings	999*
Haynies	954
Henderson	1031*
Henton	963
Hil sdale	1189
Malvern	995
McPaul	927
Minneola	1036*
Nishnabotna bottoms east of Sidney	915*
Pacific Junction	958
Percival	927
Plattsmouth, low water, Missouri river	940
Randolph	967*
Riverton	927
Sidney	1025?
Sidney, public square	1156*
Tabor	1240*
White Cloud Crossing	973*

*Estimates from aneroid measurements. The other figures are from Gannet's Dictionary of Altitudes and refer to elevation of railroad track at the depot.

STRATIGRAPHY.

GENERAL STATEMENT.

The bed rock in this region is for the most part concealed under a heavy drift sheet. The best exposures occur in the bluffs of the Missouri river and in the vicinity of Hamburg and Riverton. The oldest rocks belong to the Upper Coal Measure series. Resting on these are some remnants of Cretaceous beds, and over all lies the drift. The general relations of these divisions are indicated in the following table:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic	Pleistocene.	Post-glacial and Recent.	Alluvium, loess and terrace.
		Glacial.	Kansan and Pre-Kansan.
Mesozoic.	Cretaceous.	Dakota.	Nishnabotna.
Paleozoic.	Carboniferous	Upper Carboniferous.	Missourian.

DEEP EXPLORATIONS.

Some deep explorations have been made in each of the two counties. Seventeen years ago a boring was put down for coal at Riverton. It was made on the hill east of the village and extended down 700 feet. All that is now known about the nature of the ground is that it was mostly shale with some limestone and that there was a thin seam of coal at a depth of about 400 feet. On Mr. Rankin's farm on the northwest quarter of section 32 in Riverton township, south of Riverton, two wells have been made on the bottom lands in search of artesian water. Neither attempt was successful and the materials penetrated were mostly "soapstone," some dark shale and limestone.

At Hamburg the Hamburg Fuel and Mining Company made a diamond drill hole to a depth of 1,000 feet in 1890. The hole was sunk near the east quarter post of the northeast quarter of section 21, just outside the city limits where the ground has an

elevation of 998 feet above the sea level. Most of the core was saved, but all labels have been lost and the depth of only one piece of the core is known with certainty. This is a fragment of compact gray limestone, apparently from the Coal Measures, which was taken at 800 feet from the surface. Some men who were interested in the drilling say that red shale was encountered at about 350 feet below the surface. There was a seam of coal about a foot thick at a depth of ninety feet and a very dark shale at about 650 feet. About 400 feet of the core can yet be seen, and of this fully three-fourths is limestone, all apparently from the Coal Measures. Several pieces have a fine oolitic structrue, resembling that seen in the old quarry near Crescent in Pottawattamie county. These ledges probably dip to the south and lie here at some distance below the surface. One fact which is established beyond a doubt by this drilling is that the terranes at this point contain at least some 300 feet of limestone in the first 1,000 feet. Whether all of this thickness belongs to the Coal Measures cannot be made out with certainty, but it seems likely that such is the case. No part of the core resembles the Lower Carboniferous.

In Mills county two deep wells have been sunk at Glenwood. Both were made by churn drills. Samples of the drillings from the city well have been collected by Mr. Seth Dean and described by Norton,* who summarizes the formations as follows:

Elevation of the curb....................1,132 feet A. T.

	Thickness in feet.
Pleistocene	175
Missourian	670
Des Moines	390
Mississippian	230
Devonian (?)	135
Silurian	400

The Missourian in this well contained a considerable amount of limestone, as at Hamburg.

Some years later a well was made on the bottom land of Keg creek, in the south part of the city by the Institution for Feeble-Minded Children. The elevation of the curb is here

*Iowa Geol. Surv., Vol. VI. pp. 340-347.

980 feet above sea level and the total depth of the well is 2,000 feet. A record was taken of the strata penetrated at the time the well was made and a copy of this record follows. Some discrepancies are apparent but there is a fair correspondence in the two wells.

RECORD OF THE STRATA PENETRATED IN THE BORING AT THE INSTITUTION FOR FEEBLE-MINDED CHILDREN AT GLENWOOD.

		DEPTH BELOW SURFACE	THICKNESS, IN FEET.
1.	Drift		35
2.	Limestone		5
3.	Shale, black	40	
4.	Blue limestone	65	20
5.	Limestone	100	10
6.	Red shale	140	30
7.	Limestone	200	40
8.	Shale	256	
9.	Red shale	280	10
10.	Limestone	305	15
11.	Black shale	340	20
12.	Blue shale	360	30
13.	Limestone	430	10
14.	Black slate	445	5
15.	Soft white rock	475	4?
16.	Blue shale	479	20
17.	Red shale	499	30
18.	Limestone	529	10
19.	Black shale, coaly	549	1
20.	Sandstone	550	1
21.	Sandstone with salt water	575	7
22.	Blue shale	625	10
23.	Limestone	640	5
24.	Limestone with pyrites	655	2
25.	Green shale	690	10
26.	Red shale	715	
27.	Miner's slate	732	10
28.	Soapstone	760	10
29.	Miner's slate with pyrites	820	
30.	Sandy shale with salt water	865	
31.	Sandstone	990	5
32.	Limestone	1,010	
33.	Sandstone	1,032	
34.	Sandstone	1,065	10
35.	Brown limestone	1,103	12
36.	Red "quartzite"	1,115	3
37.	Magnesian limestone	1,198	23
38.	Gray limestone	1,226	64
39.	White sandstone	1,351	5
40.	"Soapstone"	1,410	20
41.	"Soapstone"	1,460	
42.	Limestone	1,509	20
43.	Gray limestone	1,535	
44.	"Soapstone"	1,580	3

		DEPTH BELOW SURFACE.	THICKNESS, IN FEET.
45.	"Soapstone"	1,600	2
46.	Sandy limestone	1,700	50
47.	Gypsum	1,750	2
48.	Gray limestone	1,772	30
49.	"Bastard" limestone	1,850	....
50.	Hard gray limestone	1,896	....
51.	Bottom of well	1,910	....

Gypsum occurred in the city well at depths corresponding with No. 47 above, evidently in the same terrane, and in the one Norton regards as Silurian.

CARBONIFEROUS SYSTEM.

THE MISSISSIPPIAN.

The rocks of the Upper Coal Measures in these counties consist of shales and limestones with some arenaceous beds and some marly clays. An account of their ocurrence and particular characters in different localities will be first introduced. The different localities of the exposures have been arranged in four groups as follows:

A. In and near the bluffs of the Missouri river in Mills county—sections I-VII.

B. In and near the bluffs of the Missouri river in Fremont county—sections VIII-XVIII.

C. Sections in the uplands east of Hamburg—sections XIX-XXIII.

D. Scattered outcrops—sections XXIV-XXVI.

EXPOSURES IN AND NEAR THE BLUFFS OF THE MISSOURI RIVER, MILLS COUNTY.

I. SECTION IN THE QUARRY AT HENTON.

		FEET
4.	Gray shale, with thin calcareous layers and occasional calcareous concretions from one to two inches in diameter. These concretions are compact in texture and contain some imbedded curving tubules one-fourth millimeter in diameter. Fossils: denticles of annelids, minute conical teeth, and a small productus	2

		FEET
3.	Yellow or gray limestone	1½
2.	Cream colored or gray limestone with kidneys of dark chert usually several inches in diameter. On a polished surface it is seen to hold scattered spheroidal oölitic grains from .5 to 2 millimeters in diameter and some clean fragments of shells. These lie in a copious matrix of ill defined organic granules, averaging only about one-tenth of the size of the oöliths, and these smaller granules are held together by a translucent, calcareous cement. The rock is cut by some thin fissures healed with calcite, and carrying in places small grains of iron pyrites. The chert is identical in texture with the rock	1
1.	Light, bluish gray limestone in heavy ledges, with some shaly layers and with irregular nodules of chert. It is composed mainly of a copious matrix of fine, indistinct particles in which are imbedded occassional joints of crinoid stems, some large shell fragments which are sometimes clean and sometimes covered with an oölitic crust, and elliptical granules of oölitic aspect, about one and one-half millimeters in largest diameter. Between the lower courses in the quarry are shaly, dark and carbonaceous seams containing brachiopods, spines of crinoids, and spines of archæocidaris. In one of these seams there were some fucoid-like, flat, curving bodies ranging up to 8 inches in length, nearly 2 inches wide, and from one-fourth to three-fourths inch in thickness, elliptical in outline in cross-section. The surface of these, when etched and cleaned by rain, is seen to be strewn with black, smooth, shining and round needles of pyrites, of a diameter ranging from .02 to 1 millimeter in diameter and from 1 to 6 millimeters in length, or more, tapering slightly to one end. On crushing, grinding and washing the body of these stems, small and straight siliceous spicules were obtained, of somewhat rough outline, measuring about .02 millimeters in thickness. These have been identified by J. M. Clark as sponge spicules	3

From the different ledges in this quarry, but mostly from the lower courses, there were taken the following fossils: *Archaeocidaris edgarensis, Erisocrinus typus, Eupachycrinus verrucosus, Fistulipora nodulifera, Rhombopora lepidodendroides, Ambocoelia planoconvexa, Chonetes granulifera, Derbya crassa, Pro-*

ductus cora, P. costatus, P. pertenuis, Seminula argentea, Spirifer cameratus, Allorisma subcuneatum, Chaenomya leavenworthensis, Ch. minnehaha, Solenomyn (?), *Pinna peracuta*, Bellerophon (large), other gasteropods.

About one-half mile south of Henton there is a small quarry which has recently been worked in the base of the bluffs. The section is as follows:

		Feet
6.	Yellow shale	2½
5.	Black shale	1½
4.	Limestone	1
3.	Shale, somewhat disturbed	3
2.	Concealed, about	3
1.	Limestone, one foot exposed, said to be	8

The upper four members have been exposed in exploring for coal. Another exploration was some time ago made east of this point, back of the bluff. This is reported as having penetrated much limestone, but there was no coal.

II. SECTION IN THE QUARRY NEAR THE MISSOURI BLUFFS AT MILLS STATION.

		Feet.
5.	Disintegrated limestone containing *Fusulina cylindrica*	½
4.	Yellow shale or disintegrated limestone containing *Fusulina cylindrica*	2½
3.	Limestone, decayed and yellow above, gray and sound below	3
2.	Concealed, probably shale	2
1.	Bluish, dark gray limestone	1

III. SECTION AT THE BIG SPRING IN EAST HALF OF SECTION 10, LYONS TOWNSHIP, MILLS COUNTY.

		Feet
4.	Hard gray limestone	2
3.	Blue shale	2
2.	Blue hard limestone	1
1.	Blue shale	2

IV. SECTION IN THE BLUFFS SOUTHWEST OF THE CENTER OF SECTION 10, LYONS TOWNSHIP, MILLS COUNTY.

		Feet.
7.	Bluish gray shale	2
6.	Dark limestone consisting of compact matrix containing clean organic fragments, especially spines of producti. There were also seen in a ground specimen vermicular extensions of concentrically and irregularly laminated calcareous material. Fossils: *Ambocœlia planoconvexa*, *Productus* sp.	¼

		FEET
5.	Blue shale	½
4.	Blue limestone, in places yellowish and soft. The lower part containing *Syntrielasma hemiplicata*, *Fusulina cylindrica* and an *Orthis* (?) and clean organic fragments in a fine textured, fragmental matrix	1½
3.	Arenaceous and micaceous silt with well marked joints, yellow above and bluish green below. A sample consisted of well assorted quartz particles from one-eighth to one-thirty-second millimeter in diameter, free from finer silt. It apparently contained no fossils, large or small	6
2.	Greenish or bluish gray limestone in strong and massive ledges, for the most part made up of an unassorted mixture of oölitic grains from 5 to 4 millimeters in longest diameter and mostly clean organic fragments of all sizes, imbedded in a matrix of occasionally transparent but mostly more or less distinctly fragmental and granulated calcareous matrix. In places the rock is almost perfectly oölitic. There are a few thin seams of calcite. Fossils: Small gasteropods and bivalves, crinoid stems, *Fistulipora nodulifera*, *Fusulina cylindrica*.	2
1.	Yellow shale	3

Campophyllum torquinum occurs along the base of the outcrop.

V. SECTION IN THE BLUFFS IN THE SE. ¼ OF SEC. 16, LYONS TOWNSHIP, MILLS COUNTY.

		FEET.
14.	Limestone, oölitic above and compact below	3
13.	Gray shale, with two calcareous stony layers respectively about three and one-half and four and one-half feet from the upper surface. Fossils from the shale: *Archæocideris* (spines), *Eupachycrinus verrucosus* (plates), *Scaphiocrinus* sp. (plates), *Fistulipora nodulifera*, *Polypora submarginata*, *Productus semireticulatus*, *P. nebraskensis*, *Derbya crassa*, *Spirifer cameratus*, *Chonetes granulifera*, *Bellerophon carbonaria*, *Pleurotomaria*, sp. *Allorisma* (?) sp. In one of the stony layers there were abundant individuals of *Productus nebraskensis* and also *Derbya crassa* and some bryozoa, *Chonetes granulifera*, *Discina convexa*, *Euompha-*	

		FEET
	lus rugosus, *Myalina subquadrata*, *Myalina recurvirostris* (?), *Edmondia* sp., *Aviculopecten* sp., *Entolium aviculatum*, *Pseudomonotis hawni*, *Pinna* (*peracuta ?*)	6⅙
12.	Limestone	1
11.	Marly gray shale, almost a limestone above. Fossils: Spines, plates and stem joints of crinoids. *Fusulina cylindrica*, *Rhombopora lepidodendroides*, *Ambocœlia planoconvexa*, *Chonetes vernuiliana*, *Productus semireticulatus*, *Productus* sp., *Spiriferina cristata*, *Derbya crassus*, denticles of annelids	1
10.	Limestone, with a band of chert	1¾
9.	Shale, gray and black, consisting of slightly calcareous silt, in which have been found some small streaks or pockets of coal. One of these contained a piece of fossil wood with fibro-vascular bundles resembling those of ferns. Other fossils: *Septopora biserialis* (?), *Ambocœlia planoconvexa*, *Pugnax uta*, *Derbya crassa*, *Productus longispinus*, *Euomphalus rugosus* (?), *Schizodus* (?), *Aviculopecten* (?), pygidium of a small Phillipsia and several denticles of annelids	1⅙
8.	Compact white limestone in which a *Fistulipora nodulifera* was observed. It breaks preferably along vertical planes	1
7.	A stratum of highly calcareous shale	1⅓
6.	Shale, slightly calcareous, containing occasional chitinous denticles	⅔
5.	Gray limestone, fragmental, some of the fragments clean and some covered with an oölitic crust, all imbedded in a matrix of fine texture. Fossils: *Fusulina cylindrica*, Textularia (?). The upper four inches consist of a close matting of minute tubes of an Ammodiscus with the interstices filled with clear calcite	3⅙
4.	Shaly limestone changing into rock like that in the next number	1
3.	Strong heavy ledges of yellowish gray limestone separated by seams. The ledges vary from 8 to 14 inches in thickness and encroach upon each other by alternately thinning and thickening. A polished specimen showed some clean and a few incrusted organic fragments imbedded in a	

FEET

matrix of finer fragments and structureless calcareous material. Fossils: *Fusulina cylindrica*, Textularia (?), valves of small lamellibranchs and joints of crinoid stems. In the shaly seams there is a smaller amount of matrix which is also more argillaceous and the organic fragments, consisting of worn pieces of shells, lie in a horizontal position. In these layers *Seminula argentea* and *Pugnax uta* were noted. *Fusulina cylindrica* is more abundant in the shaly seams than in the limestones.. 4

2. Concealed, probably in part containing a black, highly fissile shale (?) 4

1. Bluish gray shale................................. 4

This section is seen extending along the bluffs for nearly one-half mile, where extensive quarrying was carried on for several years. The lower shale is not all seen at one place.

VI. SECTION EAST OF THE CENTER OF SEC. 21, LYONS TOWNSHIP, MILLS COUNTY.

FEET.

12. Dark limestone full of shell fragments much weathered.. 1

11. A light gray, calcareous silt with a small admixture of fine sand and of mica scales. Fossils: *Seminula argentea* (small and flattened), *Derbya crassa* and a Bellerophon (?)........................... 5

10. Gray limestone, friable and oölitic above, compact below. The oölitic sperules have a thick and rough crust and are quite unassorted as to size, varying from .2 to 3 millimeters in diameter. The matrix, which is sparse, also contains occasional clean organic fragments. A ground specimen of the lower part of the ledge was a white, soft and structureless mass, in which lay scattered indistinct minute organic fragments and occasional clean brachiopod spines. Fossils: *Myalina recurvirostris* and some brachiopods............ 3½

9. Marly white limestone, evidently made up of a fine calcareous sand................................ 1

8. A gray shale with two thin bands of soft gray limestone about 3 and 4 feet from the top. This shale is somewhat variable in composition, being more calcareous at some levels than at others, and in places presenting a lumpy mixture of calcareous and argillaceous mud. The thin calcareous seams are quite structureless but contain occasional clean organic fragments, among which are some delicately marked tubules with white walls.

FEET

Fossils: *Textularia* (?), joints of crinoid stems, plates of *Scaphiocrinus hemisphericus*, *Fistulipora nodulifera*, *Polyopora*, sp., *Rhombopora lepidodendroides*, *Productus longispinus*, *P. prattenianus*, *P. nebraskensis*, *Chonetes granulifera*, *Derbya crassa*, *Myalina subquadrata*, *Schizodus* sp. Fossils are especially abundant in the calcareous layers which contained a *Myalina recurvirostris* and also an Edmondia.......................... 10

7. Compact, fine-grained, gray limestone, with a six inch layer of gray chert in the lower part. The limestone contains fragments of crinoid stems, shells and skeletons of bryozoa imbedded in a copious, almost structureless matrix. The rock in contact with the chert is a dolomite, apparently of the same texture as the limestone, but when examined under the microscope it is seen to be composed of small crystals. The dolomitization was evidently effected by the same conditions that segregated the siliceous material into chert. The latter exhibits the same texture as the limestone in which it lies......................... 2½

6. Gray, marly shale with a three inch layer of limestone. The upper part of this stratum is mostly calcareous, impalpable mud with scattered crinoid joints and fragments of shells. Fossils: *Fusulina cylindrica*, stems and plates of crinoids, *Rhombopora lepidodendroides*, *Derbya crassa*, *Spiriferina cristata*, *Productus* (small), *Ambocœlia planoconvexa*, *Chonetes vernuiliana* 1½

5. Calcareous, gray shale, or marl, like the above but more clayey and containing chitinous denticles and Ammodiscus and other rhizopod foraminifer remains 1

4. Black coaly shale only slightly calcareous and consisting for the most part of a fine clayey silt. Fine sand is almost absent. Fossils: denticles of different kinds.... .... ⅓

3. Compact, grayish white limestone of fine texture and having tendency to break along vertical planes. A polished specimen shows some minute organic fragments scattered through an almost structureless calcareous matrix. Streaks of travertine-like calcite occur in irregular pockets one or two inches in length. Fossils: small spires of gasteropods and Textularia (?).................... 1⅓

2. A calcareous shale, black above and yellow below.. 1

1. A light gray limestone in strong ledges. A ground specimen from the upper part was seen to be

	FEET
partly made up of rather imperfect oölitic spherules. These consist of rounded organic fragments, which have become encrusted by a thin calcareous deposit. Their sizes range from .3 to 2 millimeters in diameter. Some are flat. The matrix is in part clear, translucent calcite and in part a white, opaque, and structureless mass. A part of the specimen lacked the oölitic granules and was made up almost wholly from a matrix showing indistinct organic particles, and holding a few bits of shells. Small fissures and irregular cavities filled with clear calcite were frequent. Fossils: *Fusulina cylindrica*, *Pinna* sp. and spires of small gasteropods	4

The above exposure is in an old quarry where the lowermost ledges are now covered with debris and cannot be seen. The section is the same as the previous one, but includes two additional numbers above, and does not reach as far down.

VII. SECTION IN THE BLUFFS NEAR THE CENTER OF THE SW ¼ OF SEC. 27, LYONS TOWNSHIP, MILLS COUNTY.

		FEET.
4.	Disintegrated, shaly limestone	1½
3.	Limestone with some unassorted oölitic spherules	2½
2.	White marly shale with imbedded organic fragments. Fossils: *Fusulina cylindrica*, a small cyathophylloid (worn), plates of Archæocidaris, *Rhombopora lepidodendroides*, *Spirifer* ? (small), *Ambocœlia planoconvexa*, *Chonetes*, sp	2
1.	Compact gray limestone with imbedded organic fragments of small size	2

EXPOSURES IN AND NEAR THE BLUFFS OF THE MISSOURI RIVER, FREMONT COUNTY.

VIII. SECTION IN THE BASE OF THE BLUFFS NEAR THE CENTER OF SEC. 14, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
4.	Limestone	7
3.	Shaly material	2
2.	Marly shale with numerous specimens of *Derbya crassa* and also *Productus nebraskensis*, *P. cora* and *P. punctatus*	1
1.	Shaly material	4

Occasional small outcrops appear north of this place and to the south they are frequent. The next section is at a

point about a half mile farther south, where there is an old prospect pit for coal a short distance to the south of the north end of Wabonsie lake.

IX. SECTION IN THE BLUFF NEAR THE SOUTH LINE OF SEC. 14, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
8.	Limestone of minutely oölitic texture	3
7.	Impure limestone containing spines and a jaw plate of Archæocidaris, a small cyathophylloid coral, *Fusulina cylindrica*, *Chonetes granulifera*, *Spirifer cameratus* and *Seminula argentea*	2½
6.	A gray limestone in strong and massive ledges containing crinoid stems and sparsely studded with fossil fragments. There are also fissure-like pockets filled with travertine-like, irregularly laminated, calcareous material. These ledges are separated by thin shaly seams (best seen at 3 and 4 feet from the top of the number) containing many *Fusulina cylindrica*	11
5.	Gray limestone with more frequent fossils	½
4	Gray shale with bands of black shale containing some lamellibranchs, *Productus nebraskensis* (?) and an Orbiculoidea (?). Vermicular extensions of blue shale project into the dark bands	1½
3.	Bluish limestone with occasional crinoid stems	1
2.	Shale	1½
1.	Coal (reported)	1½
	Fire clay	?

In section 23 southeast of Lake Wabonsie, there is rock in the bluffs almost the entire distance, owing no doubt to comparatively recent undercutting of the upland by the river where it followed the channel in which the lake or slough has since formed. It was thought best to unite all the outcrops into one section as there was no difficulty in referring them to their right position relative to each other. Numbers 1 and 13 are both best exposed near the southwest corner of the section, the former in an old quarry. The same outcrops have been described by Prof. C. A. White* at an earlier time when the beds were better exposed by quarrying. His section gives a greater thickness to the lowest limestone, and in addition about eleven feet of shale, thin limestone and sandstone which were then exposed.

*Geol. of Iowa, C. A. White, 1870, pp. 358-359.

X. GENERAL SECTION IN THE BLUFF IN SEC. 23, SCOTT TOWNSHIP, FREMONT COUNTY.

FEET.

13. Dark bluish gray, almost black, limestone with some irregular seams of sandy material and occasional sinuous accretions of black chert. A hand specimen was seen to consist of a matrix of fine but blotchy and variable texture, finer where holding most fossil fragments and coarser where these are absent: In this matrix are clean and unworn fragments of unassorted sizes of shells, crinoid joints, spines of brachiopods, small bivalves and gasteropods. There are also occasional minute grains of pyrites and of siliceous material. Fossils: *Septopora biserialis*, *Fenestella* (?), *Rhombopora lepidodendroides*, Cythere (frequent) and *Productus longispinus* (?) 2½

12. Shale, gray or almost black above and yellow below. Contains many fossils near the middle. In the lower part there are round, yellow, calcareous concretions. The bulk of a hand specimen was seen to consist of a rather well assorted silt of quartz grains, free from clay. It contained thin flakes of organic shells, minute chitinous organic fragments. The fossils are mostly distorted specimens of Productus. Myalina, *Derbya crassa* and *Seminula argentea* 5

11. A somewhat disintegrated and soft, yellow, oölitic limestone of unique aspect. Two hand specimens were seen to differ chiefly in the quantity of the matrix, scanty in one and copious in the other. The matrix is compact and in places semitransparent. The oölitic spherules are unassorted, ranging in size from 1 to 3 millimeters in diameter. The larger ones especially, have a rough surface and are generally elongated and elliptical in longitudinal section, and also flattened. They mostly have a flat shell fragment for a center and this is covered by a thick deposit of irregular, wrinkled, concentric calcareous layers, rather soft. Some were seen to have been fissured as by pressure, the fissures being healed with calcite. Some dark spherules were also noted, resembling organic fragments. The matrix also held unworn and clean shell fragments and small spires of gasteropods. The mass is cut by minute, healed fissures 1

10. Gray limestone in a single strong ledge, with here and there crevice-like extensions of crystalline and travertine-like calcareous material. A ground

FEET

specimen was seen to consist of an agglomeration of organic fragments of two sizes. The larger ones range from 1 to 20 millimeters in diameter and are surrounded by a tufaceous crust of soft calcareous material of light color. These lie in all attitudes in a copious matrix of smaller encrusted organic particles averaging .2 millimeters in diameter. Bryozoa and joints of crinoid stems were noted 3½

9. Gray calcareous shale with many fossils, such as: *Rhombopora lepidodendroides*, other bryozoa, *Archæocidaris aculeata*, plates of Scaphiocrinus (?) and Zeacrinus (?) joints of crinoid stems, *Spirifer cameratus*, *Dielasma bovidens*, *Ambocœlia planoconvexa*, *Chonetes granulifera*, *Derbya crassa*, *Productus punctatus*, *P. semireticulatis*, *P. nebraskensis*, *P. prattenianus*, *P. pertenuis*, *Myalina subquadrata*, *Edmondia nebraskensis* (?), *Allorisma subcuneata*, *Nucula beyrichia* (?), *Modiola subelliptica* (?), *Aviculopecten*, sp., *Schizodus* (?), *Euomphalus rugosus*, *Bellerophon carbonaria*, *Murchisonia*, sp., *Cythere*, sp. About seven feet below the top of this shale is a ledge of limestone one foot thick. This contained a flat fish tooth. A ground specimen of this ledge was made up of a spare matrix of translucent calcite, in which were imbedded numerous minute but delicately marked tubular bodies of varying length and shape ranging from less than .1 to .2 millimeters in diameter, some being rounded and short so as to resemble oölitic grains. There are also larger rounded and incrusted flat organic fragments, some of very dark color, as well as some clean thin shell fragments, and entire small brachiopods and gasteropods.....................11

8. Limestone, with some shale, not well exposed. ... 3

7. Light gray marl with quartz particles of small size. When washed it yields fragments of echinoderms such as spines of *Eocidaris halliana*, joints of crinoid stems, spines of various echinoderms and brachiopods, chitinous denticles and Cythere 1

6 Gray, compact limestone in a single ledge, which has a decided tendency to break along vertical joints. A ground specimen is seen to consist of a matrix of minute, ill-defined, calcareous particles or mud and in this are imbedded a few large scattered clean and angular organic fragments. There are occasional cavities and fissures filled with calcite, often laminated like travertine. Fossils: spires

		FEET
	of small gasteropods and *Rhombopora lepidodendroides*	⅔
5.	Grayish yellow shale	1
4	A solid ledge of yellowish gray limestone. A ground specimen is seen to be made up of flat, rounded, organic fragments mostly from 1 to 2 millimeters in diameter lying in a horizontal position. There is hardly any matrix but the fragments are covered by an oölitic crust. Fossils occasionally seen: Bryozoa, small spires of gasteropods and joints of crinoid stems	3½
3.	Ash gray, shaly marl or limestone, yellow below, weathering into flat chips. A lump hard enough to be ground consisted of a marly, dark gray and soft matrix, with scattered clean organic fragments, and occasional small grains of quartz. Fossils noted: *Fusulina cylindrica* (gibbous), bryozoa, *Ambocœlia planoconvexa*, *Axophyllum rude*. (?) spines, body plates and jaw plates of Archæocidaris, and a foraminifer	2
2.	Strong, yellowish gray limestone, consisting of a copious mass of finely fragmental matrix holding a few scattered, rather large shell fragments and occasional fusulinas	2
1.	Solid ledges, from 4 to 10 inches thick, of a gray limestone, the ledges running in irregul rly wavy courses	5

XI. SECTION IN A RAVINE IN THE NW. ¼ OF THE SW. ¼ OF SEC 23, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
16.	Dark gray, rather hard limestone, weathering brown. A polished specimen was seen to consist of clean shell fragments from 2 to 3 or 4 millimeters in diameter, scattered in clusters in a matrix which was partly transparent. This matrix also contains tubular bodies that appear like rings in cross section, 1 millimeter in diameter or less, delicately marked. Occasionally cross sections of several contiguous individuals appear like a chain. Fossi s: *Derbya crassa*, *Fusulina cylindrica*, *Myalina recurvirostris* and some bryozoa. The rock also contains horizontally placed plates about 2 millimeters thick of vertical prismatic or fibrous structure. The material in these plates is calcite, highly bituminous and of brown color. Each prism shows delicate straight lines transverse to the axis of the prism. The edges of these plates are square. They are probably of organic origin, as fragments of some broken shells	3

		FEET
15.	Concealed (shale, marls and coal) about	12
14	Bluish gray limestone of fine texture, with some arenaceous material. It has very regular bedding planes and is cut by vertical joints. It contains calcareous cone-in-cone structures forming thin plates with fine striations on the surface	2
13.	Dark and bituminous limestone	4
12.	A dark and coaly shale	2

Number 13 in the above is identical with number 13 in the previous section. Part of the concealed strata are the shales, coal and marls described as numbers 21 and 27 in White's section already referred to and are also to be correlated with numbers 1 to 7 in the section on Indian creek (No. XII). At this latter place the first six numbers are exposed in and about a pit made in prospecting for coal.

XII. SECTION ON INDIAN CREEK IN THE SW. ¼ OF THE SE. ¼ OF SEC. 14, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
10.	Dark fissile shale	1
9.	Limestone of dark color, bituminous, weathering to brownish yellow color. When polished it is seen to consist of thin and curved, flat fragments mostly in a horizontal position. They have a thin white encrusting coat. A clastic matrix is absent but the fragments are firmly held together by what appears to be infiltered translucent calcite. Some hard red grains are to be seen, probably partially oxidized pyrites. Some siliceous material is also present	3
8.	Concealed, probably only	1
7.	Grayish yellow marly material containing a small *Productus* (*longispinus* ?) joints of crinoid stems, Ammodiscus and denticles of annelids	1
6.	Black shale	2
5.	Gray or bluish gray marly shale with a small admixture of fine siliceous sand, some mica scales and fragments of shells: Fossils: occasional small valves of *Ambocœlia planoconvexa*, a minute ostracod, frequent and well preserved Ammodiscus, and a rhizopod like Textularia	1¼
4.	Dark shale	⅚
3.	Gray shale	1⅓
2.	Coal containing brown flattened macrospores with three radiating lines on one surface, about one-fifteenth millimeter in diameter. On the horizontal cleavage plains of this coal some straight	

		FEET
	thread like impressions were noted resembling very slender leaves or stems, .01 millimeter in diameter	(?)
1	Fire clay	1½

[illegible] SECTION OF UPPER PART OF THE EXPOSURE IN BLUFF NEAR THE NORTH-WEST CORNER OF SEC. 26, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
4	A dark bluish limestone of fine texture along some layers and along other seams almost wholly made up of very small and thin shell fragments, lying flat, barely visible under a good hand lens. Thin and wavy plates of cone-in-cone and fibrous calcite occur in this ledge	2
3.	Shaly silt	1
2.	Dark gray, in places brownish, limestone, with some fossils. A ground specimen is seen to consist of thin pieces of shells, 1 to 3 millimeters across, lying flat in a sparse matrix holding also a few small quartz grains	¾
1.	An arenaceous and calcareous rock of fine texture and of bluish color, consisting of a siliceous, well assorted silt or sand imbedded in calcareous material. It contains frequent specimens of a Cythere, also a Fenestella, other bryozoa, and fragments of brachiopod shells.	2½

[illegible] GENERAL SECTION OF SEVERAL EXPOSURES NEAR THE CENTER OF THE NORTH LINE OF SEC. 35, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
9	Blue limestone weathering brown with many joints of crinoid stems and broken into a discontinuous stratum of small bowlders	(?)
8	Chocolate colored, sparingly sandy shale, marly and slightly micaceous, containing horizontal seams of small calcareous nodules of gray color	3½
7	Yellow marl with small calcareous nodules, about	5
6	Gray marl with many fossils: Ammodiscus, *Lyphophyllum proliferum* (?), *Fistulipora nodulifera* (flattened), *Rhombopora lepidodendroides*, *Septopora biserialis*, *Polypora submarginata* (?), *Fenestella* (?), *Chonetes granulifera*, *Ch. vernuiliana*, *Spirifer cameratus*, *Spiriferina kentuckensis*, *Pugnax uta*, *Syntrielasma hemiplicata*, *Ambocœlia planoconvexa* (both valves), *Productus semireticulatus*, *Murchisonia* (?), *Nucula* (?), denticles of brown color	1
5	Soft gray limestone with some fossils. In the lower part of the ledge vermicular vertical extensions of dark material were noted. The rock contains	

		FEET
	clean organic fragments in an almost structureless matrix	7
4.	Hard blue limestone with many crinoid stems and cut by vertical joints. A ground specimen shows occasional fusulinas and clean and also incrusted fragments of shells imbedded in a copious dark matrix mostly structureless, but also showing indistinct small granules. The organic particles seem to be indurated, as if by infiltration of silica, exposed about	1
	(Below this there were some 3 or 4 feet not exposed. Most of this space is apparently taken up by limestone, which has been quarried and is now covered by debris.)	
3.	Red shales containing fine quartzs and, some mica and some calcareous material. The latter is mostly gathered into gray concretions, less than 1 millimeter in diameter.	2
2.	Grayish blue, finely arenaceous silt with some mica. Some seams are hardened by the deposit of a strong intersticial cement of calcite	6
1.	Red shale	½

The above section is not quite continuous. Numbers 1, 2 and 3 are seen in the bank east of the wagon road, and the remaining numbers appear in a quarry in the slope above. About fifteen feet below its base there is seen in the ditch along the road leading west, some twenty rods distant, a limestone which is much disintegrated.

Between the road and the creek on the north line of the northwest quarter of section 31 in Green township, east of Thurman, is an old quarry now concealed. Some blocks of a sound hard limestone were seen in the rubbish which was overgrown with underbrush.

Section XV which follows is seen south of Thurman and includes two exposures about two-thirds of a mile apart. Numbers 1 to 4 are seen east of the wagon road in the northwest quarter of the southwest quarter of section 12 and numbers 4 to 6 appear in the northwest quarter of section 13, the limestone in both places appearing to be the same (number 4). Near the latter place a well was made west of the wagon road, and a limestone was encountered some forty feet below the exposed shale.

XV. SECTION OF EXPOSURES IN THE BLUFFS TWO MILES SOUTH OF THURMAN.

		FEET.
6.	Bluish gray sandstone of fine texture, cemented by a crystalline calcareous matrix	⅛
5.	Gray shale, not calcareous, evidently in part originally a black shale	10
4.	A dark gray, blotched limestone cut by straight and vertical joints into large blocks and containing numerous spheroidal calcareous lumps about one-fourth inch in diameter. In section is seen to be composed of an agglomeration of indurated lumps of calcareous mud, of all sizes up to one-half inch in diameter and of varying color due to weathering. The larger of these are themselves occasionally composed of agglomerations of smaller nodules. Some show shrinkage cracks and fissuring. In this mass are a few shell fragments, joints of crinoid stems and quartz grains	3
3.	Soft bluish gray shale (partially concealed)	2
2.	Grayish blue sandstone of fine texture and indurated by a crystalline calcareous matrix, in straight layers below and ripple bedded above	3
1.	Shale, not well exposed	1
	Concealed	40
	Limestone	3

XVI. SECTION IN A QUARRY EAST OF THE CENTER OF THE WEST LINE OF THE NW. ¼ OF SEC. 23, SCOTT TOWNSHIP, FREMONT COUNTY.

		FEET.
2.	Gray marl with fossils	1½
1.	Limestone, blue and hard below, softer, gray and more fossiliferous above. In a ground specimen the rock is seen to consist of a copious, compact, structureless and dark gray matrix, in which lie a few clean organic fragments and also some very unevenly distributed, oblate or round oölitic grains with thick crust. In places the exterior of this oölitic crust is replaced by iron pyrites. Fossils: *Rhombopora lepidodendroides*, *Productus costatus*, *P. cora*, *P. nebraskensis*, *Seminula argentea* (large), *Orthis?* (large), *Myalina swallowi*, *Avicula longa*, *Allorisma subcuneata*, *Entolium aviculatum*, *Aviculopinna americana*, *Sphaerodoma primogenius*	2

XVII. EXPOSURE IN THE ROAD NEAR THE EAST LINE OF SEC. 6, WASHINGTON TOWNSHIP, FREMONT COUNTY.

		FEET.
2.	A decayed limestone originally dark in color and containing sand and mica scales, being largely a mixture of encrusted shell fragments and calcareous mud	⅛
1.	Gray shale, originally dark	2

XVIII. GENERAL SECTION OF THE EXPOSURES NEAR THE HIGH SCHOOL IN HAMBURG.

FEET.

7. Gray shale, somewhat disintegrated and leached, giving no response to acid and evidently originally dark, containing disc-shaped concretions of iron pyrites about an inch in diameter and a few thin seams of arenaceous material above. When washed it yielded brown scales of rhomboid form, some fine, tubular and jointed bodies and a rhizopod resembling a textularia.................15
6. A dark gray, arenaceous limestone with occasional scales of mica. On a polished surface the sand grains were seen to measure from one-eighth to one-fourth millimeter in diameter. In the main it is breccia of organic fragments with a sparse matrix, one-half of the bulk of the rock consisting of organic fragments more than one millimeter in diameter and surrounded with a crust of structureless material. There are also some imbedded minute tubules about one millimeter in diameter. Occasionally there are imbedded lumps of lighter color. Fossils: Bryozoa, fish teeth (?), chitonous denticles of small size, and poorly preserved specimens of Ammodiscus.......................... ¾
5. Gray, calcareous and arenaceous shale............. ¼
4. Bluish gray rock consisting of fine sand and organic calcareous fragments slightly encrusted.......... ⅓
3. Shale.. 4
2. Fine-grained, blue sandstone with a crystalline calcareous cement and showing ripple marks..... 2
1. Shale, micaceous, arenaceous and slightly calcareous, exposed................................ 1

These exposures are somewhat scattered, some being seen on the street north and some on the street south of the high school grounds. A ledge of limestone was also seen below the bluff to the north near some wells which furnish part of the city water. This probably corresponds with number 6 in the above section.

SECTIONS IN THE UPLANDS EAST OF HAMBURG.

XIX. SECTION IN THE CREEKS IN SE. ¼ OF SEC. 13 AND ADJOINING QUARTERS OF SECS. 18 AND 24, TWO MILES EAST OF HAMBURG.

FEET. INCHES.

26. Gray shale, not calcareous, composed of fine silt and containing very little arenaceous material....................................... 7
25. Dark gray marl, composed largely of minute

		Feet.	Inches.
	organic fragments. Fossils; *Rhombopora lepidodendroides*, *Ambocœlia planoconvexa*, *Ammodiscus* (?) and minute conical fluted fish teeth, rhomboidal, brown, small but thick enameled fish scales (measuring one-third millimeter across), spines and flakes of brachiopod valves	1	
24.	Dark, almost black, arenaceous limestone. In a polished specimen it is seen to consist of a matrix of fine calcareous material mixed with fine quartz sand and a few mica scales. In this are embedded numerous worn fragments of shells and other animal remains, and also occasional lumps of greenish clay and calcareous material. All of the fragments have a more or less calcareous, accretionary crust. In some cases the fragment is small and the crust thick so as to make true oölitic sperules with organic centers. Joints of crinoid stems occur. Some of the calcareous lumps are a half inch in diameter and have concentric layers surrounding a dark structureless center showing healed shrinkage cracks. The shell fragments range in size from 2 to 10 millimeters. Fossils observed: *Derbya crassa* and *Rhombopora lepidodendroides*	1	
23.	Fine-grained, bluish and micaceous sandstone weathering to yellow and brown. The sand is cemented by a crystalline calcareous matrix The sand is well assorted, consisting mostly of grains ranging from one-fourth to one-sixteenth millimeter in diameter and with angular contours. A few grains have a green color		10
22.	Micaceous and arenaceous, grayish blue silt or shale of finer texture than the previous number, and lacking the calcareous cement, but otherwise of similar composition	3	
21.	Seam of sandstone like number 23		6
20.	Blue shale like number 22	2	6
19.	Ripple bedded sandstone like number 22		8
18.	Concealed	?	
17.	Gray shale	4	
16.	Dark, shaly and soft limestone more indurated above and softer below, filled with fossils and containing bits of black woody tissue. In a polished specimen it is seen to consist of an unassorted mixture of clean shell fragments of all sizes and impalpable calcareous mud.		

		FEET.	INCHES.
	There is also a very small admixture of minute quartz particles and some granules of pyrites of iron. Fossils: *Derbya crassa*, *Pleurotomaria perhumerosa?* *Spirifer cameratus*, *Productus punctatus*, *P. semireticulatus*, *P. longispinus*, *P. costatus*, *Chonetes granulifera*, *Ambocœlia planoconvexa*, *Macrodon tenuistriatis*(?) *Edmondia nebraskensis* (?) *Myalina*, *Nucula* (?) *Schizodus* (?) *Rhombopora lepidodendroides*, joints of crinoid stems, chitinous denticles of annelids and calcareous tubules....................	3	
15.	A pure coal with black streak and with thin horizontal seams of charred woody fibre. When ground it yields frequent macrospores, flattened, brown, two-thirds millimeter in diameter with three radiating ribs on one face. At the outcrop the thickness is only	1	2
14.	Yellowish, evidently somewhat weathered fire clay, seen	1	
13.	Concealed......	?	
12.	Shale, highly weathered and including above some indistinct, highly disintegrated layers of gray, yellow limestone or marly beds	22	
11.	Dark limestone, easily broken and containing many fossils. When ground and polished it is seen to be an organic breccia with a somewhat copious and dark argillaceous matrix. The shell fragments are clean and somewhat rounded by attrition. It contains horizontally placed thin seams of brownish and vertically fibrous calcite. Fossils: Joints of crinoid stems, *Rhombopora lepidodendroides*, other bryozoa, *Productus nebraskensis*, *Bellerophon montfortianus*, Schizodus (apparently several species), *dentalium* (?) and Ammodiscus		7
10.	Dark shale	3	6
9.	Dark, almost black limestone. In a polished sample it is seen to be an unassorted shell breccia, in which the matrix is very sparse. The fragments are clean, and mostly unworn. Mingled with these are some round lumps of compact, apparently clastic, calcareous material. Throughout the mass there are small tubules from .05 to 2 millimeters in diameter, curved and sometimes placed side by side in rows, or other groups. Granules of pyrites occur. When crushed and washed the rock yields some small lamellibranchs.............		3

	FEET.	INCHES.
8. Dark bluish shale, weathering to yellow	3	
7. Concealed, probably shale, about, ...	3	
6. Grayish, light colored limestone. On a polished surface it is seen to consist of a copious, almost structureless and compact matrix which is fissured by many minute joints healed with calcite as if incipiently brecciated. In this matrix are held frequent fusulinas and a few scattered shell fragments of about the same size. Fossils: Joints of crinoid stems, *Fusulina cylindrica*, *Rhombopora lepidodendroides*, *Productus semireticulatus*	2	
5. Concealed	?	
4. Limestone, yellowish gray, very much decayed above. A sound hand specimen exhibited a texture and structure like that in number 6, except that it contained some lumps showing a lighter color than the rest of the mass. Fossils: *Septopora biserialis*, *Fistulipora nodulifera*, *Fusulina cylindrica* (long and slender), jaw plate of Archæocidaris and joints of crinoid stems	4	
3. Shale, dark bluish gray below and yellow above. a sample from the lower part contained a few mica scales and was also calcareous	8	
2. Concealed	4	
1. Greenish, dark gray limestone with many fusulinas and consisting of a copious matrix of fine texture containing unassorted organic fragments. Fossils; crinoid stems, some bryozoa, small gasteropods, *Fusulina cylindrica* (long and slender, sometimes twisted, forms) .	1	

Numbers 1 to 4 appear in a creek a little south of the center of section 13, close to the wagon bridge. Numbers 6 to 12 are seen about a quarter of a mile farther up in the same creek, at successive points. Numbers 14 to 17 outcrop close to the west section line in the creek in the southwest quarter of the southwest quarter of section 18 (Tp. 67 N., R. XLI W.), and numbers 18 to 25 appear in a tributary from the south in section 24 (Tp. 67 N., R. XLII W.). Though separated by a distance of about a half mile it is quite evident that they occur in the succession indicated.

XX. OUTCROP UNDER THE BRIDGE ONE-QUARTER OF A MILE WEST OF THE SOUTHEAST CORNER OF SECTION 18. MADISON TOWNSHIP, FREMONT COUNTY.

The following outcrop is probably included in the highest number of the previous section.

		Feet.
3.	Dark compact limestone with clean shell fragments, only loose blocks seen	?
2.	Concealed	?
1.	Blue shale, free from calcareous material and containing no fossils	5

XXI. SECTIONS IN TWO WELLS IN THE SW. ¼ OF SEC. 1, TP. 67 N., R. XLII W.

Bridges' Well.

		Feet.
3.	Drift and probably shale	39
2.	Disintegrated limestone with Productus and other fossils, about	1
1.	Coal, about	1⅓

McMillan's Well.

		Feet.
2.	Drift	48
1.	Blue sandstone of fine texture with some shale	8 ?

Bridge's well has its curb about fifty feet below McMillan's well and the coal which was explored there no doubt lies some distance under an arenaceous rock which was penetrated near the bottom of Bridges' well. Both of these wells are near the south line of the section, and the latter is farthest to the east. Another of Bridges' wells is on higher ground about 80 feet above his lower well. The section of this one is as below:

XXII. SECTION OF BRIDGES' UPPER WELL, IN THE SW. ¼ OF SEC. 1, TP. 67 N., R. XLII W.

		Feet.
7.	Drift	30
6.	Shale	12
5.	Coal	1½
4.	Shale	5½
3.	Limestone	1
2.	Shale with some seams of limestone	24
1.	Limestone	4

The elevation of the curb of this well is about 1,030 above sea level, or about 130 feet above the bottoms to the west.

XXIII. SECTION ON MILL CREEK NEAR THE CENTER OF THE SW. ¼ OF SEC. 33, RIVERTON TOWNSHIP, FREMONT COUNTY.

		FEET.
9.	Shale, yellow and weathered	10
8.	Three or four ledges of solid and strong limestone separated by seams of greenish shale. One of the ledges from the lower part of the number is a gray rock and contains copious clean fragments of crinoid stems, brachiopod shells and plates and spines of *Eocidaris hallanus* (?). One of the ledges above is unique in structure. It is hard and white, and is composed of thin and rounded fragments of shells, all horizontally placed. They measure from 1 to 2 millimeters in width, and lie embedded in a matrix of clear crystalline calcite. The fragments themselves appear as if consisting of the same material, their outlines merely being marked by thin white lines. Occasional specks of iron pyrites appear. On one surface of this ledge were noted: *Myalina swallowi* (?) *Aviculopecten whiteyi* and *Bellerophon marcouanus*	3
7.	Yellow, slightly ocherous marl, or decayed limestone	2½
6.	Blue calcareous shale with yellow blotches and small compact concretions above. Organic fragments and some sand grains occur	4
5.	Concealed, probably limestone, about	2
4.	A thin seam of soft sandstone composed of fine quartz grains, well assorted, with some mica	1/6
3.	Friable and somewhat shaly silt with some seams very micaceous	4½
2.	A fine-grained and micaceous sandstone firmly cemented by crystalline calcite, varying in color from bluish gray to brown, and containing occasional small joints of crinoid stems	2
1.	Bluish gray shale interbedded with reddish arenaceous seams, somewhat micaceous. Large and ramifying calcareous concretions are lodged in vertical or inclined joints which appear on the exposed surface	8

SCATTERED EXPOSURES.

The narrowing of the Silver creek bottoms south and west of Malvern indicates the presence of bed rock. It rises above the level of the bottom in some places along the bluffs in section 5, Tp. 71 N., R. XL W., and limestone has been quarried at a few points, including the place where the following section was observed.

XXIV. SECTION NEAR THE BANKS OF SILVER CREEK ONE-THIRD MILE WEST OF THE CENTER OF SECTION 5, WHITE CLOUD TOWNSHIP, MILLS COUNTY.

		FEET.
6.	Marly shale	½
5.	Grayish, cream-colored, fusulina limestone in three or four strong ledges. The fusulinas with some large sized fragments of shells, lie imbedded in a matrix consisting of a compact mass of minute fragments of organic material. About 14 inches below the top of this number it contains a layer of black and in places gray chert, with the same texture, including the fusulinas. Fossils: *Fusulina cylindrica*, *Syringopora*, sp., a small gasteropod and a small cyathophylloid coral. (This number is largely removed by cavern erosion. The walls of the old caverns are in places covered by a stalactitic crust, and the cavities are filled with bluish cavern clay)	6
4.	Grayish blue, compact limestone, having some fragments with oölitic crust	⅔
3.	Concealed	2
2.	A yellow limestone, breaking into thin, small, irregular slabs from one to three inches in thickness. It is composed of a compact matrix of calcareous mud, in which are imbedded clean fragments of crinoid stems, bits of shells and a few bryozoa and *Fusulina cylindrica*	2
1.	Limestone, quarried, but now concealed, about	3

In the bed of Spring Valley creek a short distance to the south of the center of the north line of section 36 Rawles township, Mills county, some limestone was once quarried. The section is as given below. The quarry is now covered. The upper ledge is said to have been scored, the striae bearing in a northeast-southwest direction. Some rocks beautifully scored from this edge may yet be seen in the cellar of Mr. John W. Glynn's house.

XXV. SECTION IN SPRING VALLEY CREEK, IN SEC. 33, RAWLES TOWNSHIP, MILLS COUNTY.

		FEET.
3.	A dark bluish compact limestone containing some clean and some encrusted organic fragments of varying sizes, among which some small spires of gasteropods and some joints of crinoid stems were noted. Loose pieces of fusulina bearing rock were observed	1⅙
2.	Shale, dark, not well exposed	2

	FEET.
1. Compact, yellowish white limestone with irregularly tubular and fissure-like ramifying cavities, averaging one millimeter in diameter and filled with clear calcite. The rock consists of minute organic particles among which are numerous curving tubules, less than one-tenth millimeter in diameter. Along some irregular streaks the rock is quite opaque and white, but otherwise like the rest in structure. These streaks are trenchantly marked off from the rest on a ground surface	1½

XXVI. SECTION IN AN OLD QUARRY ON PLUM CREEK IN THE SW ¼ OF SEC. 17, GREEN TOWNSHIP, FREMONT COUNTY.

	FEET.
2. Grayish yellow marl containing fragments of *Septopora biserialis*, spines of various kinds, joints of crinoids and small oval shells of some ostracods	3
1. Yellowish white limestone consisting of a matrix of minute organic fragments with oölite incrustations. In this lie imbedded larger oölitic sperules with centers of dark organic fragments surrounded by thick crusts of concentric layers. The largest measure 2 millimeters in diameter. The rock is cut by some minute fissures healed by crystalline calcite	2 ?

The quarry has been abandoned and is now almost wholly covered by wash from the creek. The above section lies about fifteen feet above the water in the creek.

Correlations.—On comparing the sections just described it will be seen that V, VI, VII, VIII, IX and X are composed of the same limestone with the same shales overlying in V, VI and X. Sections I, II, III and IV probably underlie these, the latter at no great distance below. Numbers 4, 5 and 6 in XIV are perhaps identical with the lower main limestone in V and VI. Number 9 in XII and 16 in XI are identical. Number 8 in XXIV is probably the same as 4, 5 and 6 in XIV. Number 15 in XIX and number 2 in XII are apparently equivalents, and as 4 and 6 in XIX resemble 1-4 in X, the exposures in the region around Hamburg, which are represented by 12-26 in XIX, probably overlie all of the rocks exposed in the country north of Thurman. The limestone near Malvern, seen in section XXV, is identical with the main limestone east of Wabonsie lake, 3-5 in V. A general section for the two counties would hence be about as follows:

GENERAL SECTION.

		FEET.
8.	Shales, with one or two thin seams of limestone (19-26, XIX)	20
7.	Limestone and some shale (3-9, XII)	5
6.	Coal (2, XII, 15, XIX)	1½
5.	Shales with some thin seams of limestone (7, 8, XV).	30
4.	Two or three ledges of limestone with some interbedded shale (10-14, V, 5-10, VI)	15
3	Limestone in strong quarry ledges (3-5, V, 1, VI, 1-4, X)	12
2	Sandy shales with seams of limestone (III and IV)	10
1.	Limestone (I and II)	8
	Total	101½

Number 3 in this general section is the equivalent of the principal quarry ledges at Macedonia in Pottawattamie county and numbers 5, 6, 7 and 8 are the equivalents of the upper part of the section in the bluffs below Nebraska City, Nebraska. The coal, number 6, is probably not the Nodaway. At least it differs from this in always containing a notable number of macrospores which the Nodaway coal does not. The limestone in V, VI, VII and VIII is believed to be the equivalent of numbers 1-3 in Meek's Rock Bluff sections in Nebraska.* The entire section, including all the Coal Measure rocks exposed in the two counties, belongs to the Missourian stage, and presumably overlies the Nodaway beds of the same stage.

Geographical Conditions: Fauna and Flora.—The geographical conditions under which the Missourian deposits were laid down are to be made out from the physical character of the beds themselves as well as from the plant and animal remains which they contain. These indicate off-shore conditions, such as prevail on a continental shelf, alternating with more shallow and less open waters. A considerable part of the shales contain fine, arenaceous material such as is common in the deposits out on a continental shelf. The limestones indicate a still more open sea. The coal seams and the black and clayey shales, on the other hand, were laid down in lagoons near the shore. Plant remains are rather scarce even in connection with the coal seams, which themselves have a small development. The presence of Fusul-

* Report on the Paleontology of Eastern Nebraska, F. B. Meek, p. 95.

ina, of Ammodiscus, of other foraminifera and no less the abundance of echinoderms and especially crinoid remains, testifies to the presence of deeper waters at intervals. Below is given a classified list of the fossils noted.

PLANTS.

Ferns, wood and macrospores.

ANIMALS.

PROTOZA.

Ammodiscus.*
Fusulina cylindrica.
Textularia ?.
Rhizopod (plates).
Rhizopod (tubes).

SPONGES.

Sponge (*undet*).

COELENTERATES.

Axophyllum rude.
Campophyllum torquium.
Cyathophyllum (small).
Lophophyllum proliferum.

ECHINODERMS.

Archæocidaris aculeata.
edgarensis.
Archæocidaris (spines.)
Archæocidaris (plates).
Archæocidaris (jaw plate).
Eocidaris halliana.
Erisocrinus typus.
Eupachycrinus verrucosus.
Scaphiocrinus (plates).
Scaphiocrinus hemispherica.
Zeacrinus (?).
Crinoids (stems).
Crinoids (plates).

BRACHIOPODS.

Ambocœlia planoconvexa.
Chonetes granulitera.
vernuiliana.
Fistuliopra nodulifera.
Polypora submarginata.
Rhombopora lepidodendroides.
Septopora biseralis.
Syringopora.
Bryozoa (undet).

ANNELIDS.

Annelid denticles.

GASTEROPODS.

Bellerophon carbonaria.
marcouanus.
montfortanus.
Bellerophon (undet).
Dentalium.
Euomphalus rugosus.
Murchisonia.
Pleurotomaria perhumerosa.
Pleurotomaria (undet).
Sphaerodoma primogenius.
Gasteropods (undet).

LAMELLIBRANCHS.

Allorisma subcuneatum.
Allorisma (undet).
Avicula longa.
Aviculopecten whileyi.
Aviculopecten (undet).
Aviculopinna americana.
Chenomya leavenworthensis.
minnehaha.
Edmondia nebraskensis.

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*Foraminifera are present in the entire section of these two counties, more or less frequently, excepting the sandstones and the coarse silts. They may be fouud by washing the marls, clays, and crushed limestone. Specimens have been submitted to Dr. E. Schellwein of Königsberg, Germany, who has identified two species of Ammodiscus belonging to the subgenus Psammophis, and an Endothyra, probably identical with *Endothyra parva* Möll. Dr. Schellwein reports that one of the species of Psammophis resembles *P. inversus*, but the shells have a more irregular structure. In the quarry northwest of Bartlett the upper part of one of the ledges of limestone consists of a felt of the irregularly curving tubular shells of this species, the interstices having been filled with a transparent hard matrix of calcite. This layer varies from three to five inches in thickness and runs the whole length of the quarry. It was also noted in the same ledge about four miles farther south.

Chonetes (undetermined).
Derbya crassa.
robusta.
Dielasma bovidens.
Orbiculoidea convexa.
Orthis (undet).
Productus cora.
costatus.
longispinus.
nebraskensis.
pertenuis.
prattenianus.
punctatus.
semireticulatus.
Productus, (undet).
Pugnax uta.
Seminula argentea.
Spirifer cameratus.
Spiriferina cristata.
kentuckiensis.
Syntrielasma hemiplicata.
Brachiopods (undet).

BRYOZOA.

Fenestella.

Edmondia (undet).
Eutolium aviculatum.
Macrodon tenuistriatus (?).
Modiola subelliptica.
Myalina recurvirostris.
subquadrata.
swallowi.
Myalina (undet).
Nucula beyrichia (?).
Nucula (undet).
Pinna peracuta.
Pseudomonotis hawni.
Schizodus wheeleri (?).
Schizodus (undet).
Solenomya (undet).
Solenopsis solenoides.
Lamellibranchs (small).

OSTRACODS.

Cythere (undet).
Ostracods (undet).
Phillipsia (undet).

FISHES.

Fish scales.
Fish teeth (conical).

THE CRETACEOUS.

After the Coal Measures had been laid down the bottom of the sea was elevated and became land. This condition apparently prevailed during the greater part of the Triassic and Jurassic ages, for no deposits of this time occur here. The lands formed from the Coal Measure sediments were then subjected to erosion and how much of the original formation was carried away cannot now be told, but a thickness of some hundreds of feet may very well have been removed. The conditions were again reversed at some time during the Cretaceous age and the region was submerged anew and covered by sediments of a new sea. These later deposits are quite different in appearance from the older and resemble in this country the Dakota formation of the Western Plains.

During the Tertiary age, after the sea for the last time disappeared, the Cretaceous deposits were in their turn carried away

and all that now remain of them are a few remnants of the lowest part of the formation.

There is no doubt that small patches of Cretaceous deposits lie under the drift in several places on the uplands, where they cannot now be seen. Sand and soft "sand-rock" have been found under the bowlder clay a mile east of Emerson. Another well in the west bluffs of the Nishnabotna west of Henderson penetrated some gravel which may have been of the same age. On the eroded surface of the limestone in the quarry at Henton there are seen some disintegrated lumps of a brown sandstone which resembles the Cretaceous in appearance. It contains almost exclusively well rounded pebbles of quartz and chert. Blocks of the same conglomerate, always highly ferruginous, occur associated with small exposures of Coal Measure rocks two miles farther south and have again been noted on top of these older rocks east of Wabonsie lake in section 23, Scott township, Fremont county. The clay which fills the caverns in the limestone south of Malvern is probably also of the same age, and the same may be said of a highly disintegrated, ferruginous and soft clayey rock resting on the eroded surface of the Coal Measure limestone southeast of the center of section 13, Tp. 67 N., R. XLII W.

While the age of the small outcrops enumerated above must be regarded as uncertain, the Dakota sandstone can be positively identified in two exposures in Mills county. One of these is in the low slope of the east bluffs of the Nishnabotna a little south of the center of the northeast quarter of section 22, two miles south of Henderson, and the other is half a mile distant, northeast of the southwest corner of section 14. Sandstone was quarried for many years at the former place, but the quarry is now partly filled. The face of the quarry appears to have been about ten feet high. The rock is a gray sandstone in heavy ledges, in places yellow or even brown. It breaks with equal readiness in all directions. Where the rock is hardest, the sand grains are held together by an opaque, white, thin layer of siliceous cement which apparently is a product of interstitial leaching and redeposition. The solvent effect of underground waters are seen

also in the absence of the ferruginous cementing material which is common in the Dakota sandstone elsewhere, and which makes the sandstone in section 14 almost black. In the quarry in section 22 the yellow or red oxides of iron color the rock in places where perculating water has not had free passage, as along shaly seams and in concretions. At the base of the quarries the sandstone rests on gray clay, or is interbedded with this, and on the faces of some ledges there are marks which show how the two kinds of sediments, while yet in a plastic slate, have been worked into each other and broken into lumps which have slid into new positions, evidently under pressure of superincumbent sediments.

The sediments are of the littoral kind: mud, sand and gravel alternating. It is the first deposit of the advancing sea. The gravel is well worn, and consists largely of the most resistant material of the underlying Coal Measure rocks. No limestone fragments were seen, but in one block were some angular cavities which might have contained chips of such rock, afterward removed by solution. A study of several lots of pebbles of various sizes show that the larger ones are mostly made up of chert from the Coal Measures and this often contains silicified fragments of fossils. Most of the finer material is common quartz, as may be seen in the following table, which is based upon observations of several hundred pebbles and grains of the conglomerates and sandstonts. Evidently the larger fragments are nearly all derived from the local rocks, the more resistant material of the Missourian.

TABLE SHOWING AVERAGE FREQUENCY OF DIFFERENT MATERIALS AMONG FRAGMENTS OF SUCCESSIVE SIZES IN THE CRETACEOUS ROCKS NEAR HENDERSON, IOWA.

Average diameter of fragments in millimetres.	8-4	4-2	2-1	1-½
MATERIALS.	PER CENT.	PER CENT.	PER CENT.	PER CENT.
Black chert	37	7	5	1
White chert	27	27	5	1
Shale	3	2	0	0
Clear quartz	3	25	57	82
White or yellow quartz	22	29	23	14
Pink colored quartz	8	10	10	2
Chert of both kinds	64	34	10	2
Quartz of all kinds	33	64	90	98

The concretions already referred to are remarkably like those occurring in the Dakota sandstone of the West. They are more numerous in some of the ledges than in others. On one block no less than seventeen were counted on a surface of one square foot. They are usually spherical in shape, but in a lot of fifty, six were double and dumb-bell shaped. In these one of the pair is always slightly smaller than the other. The spheres range in size from five to fifty millimeters in diameter. In a lot of fifty-five the different sizes were represented as follows:

Sizes in millimeters.	5	6-10	11-15	16-20	21-25	26-30	31-35	36 40	41-45	50
Number of concretions of different sizes	1	4	11	12	12	5	5	2	1	1

The interior of most of them consists of sand grains of the same kind as in the rock outside, with a loose packing of yellow ochre or clay, probably a residuum after pyrites of iron. In other cases the center consists of a lump of clay.

In section 14, northeast from the old quarry, the rock is brown, and in places almost black, sandstone with a conglomeritic layer on top. It is cut at one point by old worn joints into long and narrow blocks. A thickness of only a few feet is exposed and the ledge runs for some rods at the foot of the slope.

No fossils occur at either of the two outcrops. Their age has been sufficiently discussed in the reports on the adjacent counties. They evidently belong to the same epoch as the Dakota sandstone of the Plains.

Erosion Interval.—After the Cretaceous sea had disappeared the land was again subjected to erosion during the Tertiary age and reduced to the present level of the bed rock. A considerable thickness of the latest sediments may thus have been washed away and also a part of the Coal Measures when this period was brought to a close by the coming of the ice age.

Pleistocene.

Ante-Glacial Silt (?).—During the glacial period the land in this region was covered by a great continental glacier, which formed a heavy deposit of bowlder clay. Under this clay lies in some places a silt, which frequently is highly calcareous and in other respects also seems to be closely related to the drift. Sand and gravel is occasionally associated with this silt and inter-bedded with it. In one place a tunnel-like hollow in the silt is seen to be filled with sand. This is in the Misouri river bluffs a little south of the center of section 32, Oak township, Mills county. In other places it has been much affected by water, which has percolated through porous strata and deposited white calcerous flour and sometimes a dark material like wad. An instance of this appears in the base of the bluffs a little east of the center of the north line of section 5, Plattsville township, Mills county. It is here regularly laminated and grades above into a loess-like material. Below it is variable in color, changing from gray to green, purple, yellow and almost white. At another place in Mills county it appears to have been broken up or kneaded into irregular lumps, which are separated by seams of other clayey material. This was noted in a fresh excavation seen north of Henton station during the summer of 1900. The section was as follows:

		FEET.
10.	Loess	5
9.	Pebbly drift, somewhat disturbed	3
8.	Chocolate colored clay or silt	5
7.	Alternating layers of fine silt and yellow clay with lumps of soft white calcareous material	2
6.	Fine gray silt	1
5.	Fine gray sand with white concretions of calcareous matter	4
4.	Yellow clayey sand	⅔
3.	Gray cross-bedded sand	4
2.	Brown mortar rock (Cretaceous ?)	2
1.	Limestone (Coal Measures)	?

The dividing plane between the silt and the bowlder clay at this place was irregular and not unlike an unconformity, but as the bowlder clay was evidently disturbed by settling, the two may very well have been conformable originally.

The pebbles which occur in this silt and sand are mostly chert and of the kind found in the sand of the present Missouri river and it is possible that it may be a river silt of preglacial age, but judging from general appearances and from its association with the glacial drift the present writer is inclined to the view that it was made contemporaneously with the glacial drift, and probably at a time when the great river and the ice were contesting the ground. A somewhat different view is taken by Prof. J. E. Todd, who has made many observations on the same silt in this region. As it resembles the ante-(immediately preceding) glacial silt noted in other parts of the state, that designation is here retained.

The Bowlder Clay.—There is hardly any evidence as to whether the bowlder clay of these two counties belongs to one and the same ice invasion or to two or more. Exposures are few and in digging wells the bowlder clay is usually found to be quite continuous below the loess down to the bed rock. It contains no well defined sheet of sand or other demarkations. The lower part is usually dark and contains pieces of wood and fragments of coal, like the Albertan drift farther east. The upper part is more frequently yellow and weathered like the Kansan drift. Probably both are present, although there is no way of definitely distinguishing the one from the other. Occasionally wells have gone into yellow and almost red, oxidized drift under the dark bowlder clay, but such changes may very well have been caused by local underground leaching and oxidation.

Much of the bowlder clay has been removed by post-glacial erosion, as can be made out from the topography of the region, and the erosion has been most effective to the west where the thickness of the bowlder clay is least, averaging perhaps only about seventy-five feet. On going away from the Missouri the thickness increases and along the east side of the two counties it is as much as 200 feet in some places and averages at least 150 feet. Most of what is known about the bowlder clay in these counties has been learned in making deep wells. One such well was recently made at Tabor by Mr. D. L. Horne of Gretna, Nebraska, who has kindly furnished a record of the material ex-

plored. This record, which may be regarded as typical, is as follows:

		FEET.
7.	Top soil	3
6.	"Clay" (loess) with water below	80
5.	"Hard pan" (glacial till) with some sandstone and water below	77
4.	Sand, hard, with water	10
3.	"Sea mud" (glacial silt ?)	42
2.	Limestone with some shale	35
1.	"Slate" and a thin seam of coal	15

The erratics of the drift are of the same character as in Pottawattamie county. Large bowlders are scarce, very few more than three feet in diameter having been noted. It is not without interest to note that a piece of copper, weighing a half ounce, was found in heavy quicksand 220 feet below the surface in a well made near the center of the northeast quarter of section 18 in Rawles township, Mills county. It illustrates the wide distribution of the rocks of the Superior region over the area of the drift.

The Gumbo.—In some places the bowlder clay is overlain by a reddish yellow, clayey deposit, more or less like the loess but less porous, owing to the presence of a fine, ochreous, intersticial material. This gumbo is always thoroughly leached, never calcareous, but in some places it contains scattered pebbles. The latter phase was observed near some of the remnants of flat uplands southeast of Minneola. The transition from this gumbo to the loess above is usually well marked, as may be seen at Emerson north of Riverton, and also around Malvern. The gumbo is probably an old loess, in places mingled with sediments in former ponds or lakes on the old drift plain. At other points it is probably composed of old alluvial deposits.

THE LOESS.

The loess covers the uplands almost everywhere and is also to be seen on all alluvial terraces. Only where the upland slopes are quite steep does the bowlder clay come to the surface. The average thickness of the loess is estimated at about sixty feet, but in the bluff of the Missouri river and for two miles east, it

frequently attains a thickness of a hundred feet and is occasionally 150 feet. This marked thickening causes an ill defined ridge along the west border of the uplands in some places but it has been so greatly affected by erosion that it now exists merely as a skeleton of divides among labyrinths of gullies and ravines. On alluvial terraces the deposit is far less heavy, ranging from five feet on the lower terraces to thirty or forty feet on the higher ones near the bluffs of the Missouri.

In its structure the loess is of the common type, a highly porous, dust like deposit, grayish yellow toward the Missouri river and more yellowish farther east, fracturing most easily vertically and horizontally and when undermined always breaking so as to expose vertical walls. Ocasionally it contains ocherous seams on the uplands and these have a tendency to conform somewhat in their course to the surface of the land. Calcareous concretions are common in many localities but they are mostly of small size and irregular shape in these counties.

A singular structure, which the writer has previously observed in Pottawattamie county occurs here also. It consists of fluted horizontal shearing planes. Such shearing planes were noted in the lower part of the loess in the wagon road leading up the bluff north of the East Nishnobotna, north of Riverton, and on the side of the wagon road running north and south near the center of the east line of section 31, Tp. 73 N., R. XLII W. Their direction at the latter place is N. 25° W. The most extensive development noted is at the foot of the south bluff of Keg creek in Glenwood. In Hall's brick yard flutings are seen in the clay pit and appear again to the northeast in several places. Their direction varies here at different points, N. 68° W., E-W, W. 7° S, having been noted.

An instance of a pebble-bearing loess occurs in the bluffs just north of Henton. A vertical wall about twenty feet high is exposed. The upper one-third of this loess is quite typical in its aspect and carries the common loess pulmonates. This changes below into a sandy deposit mingled with loess, pebbles and some broken shells of land snails. The pebbles are confined to an irregular seam or streak. Below this is again a loess-like, gray

Loess ridge and alluvial plain of the Missouri river west of Hamburg. Photo by H. H. Stich.

material separated by wavy, joint-like lines into laminæ about one-half inch thick. Below this the talus conceals the section, which however appears to contain some bowlder clay and gravel. An examination of the pebbles showed that many of them were scored and that in other respects they resembled unworn and fresh pebbles of the glacial drift of the region. The limestone pebbles are mostly from Coal Measure strata. The following table shows the proportions in percentages of the different kinds of rocks which are represented in the different sizes of about 250 pebbles examined.*

KIND OF ROCK.	ONE INCH IN DIAMETER; FREQUENCY IN PER CENT.	ONE-THIRD INCH IN DIAMETER; FREQUENCY IN PER CENT.	ONE-NINTH INCH IN DIAMETER; FREQUENCY IN PER CENT.
Quartz	2	3	10
Granite	10	13	15
Greenstone	5	2	1
Hornblende rock	0	0	2
Schists	5	2	1
Jaspilite	2	0	0
Diabase	26	17	10
Quartzite	2	4	2
Sioux quartzite	3	1	1
Dolomite	5	8	5
Chert	3	5	6
Limestone	33	42	44
Clay ironstone	2	1	0
Cretaceous	2	2	3
Silicified wood	0	1	0
Sandstone	....	....	1

At the foot of the loess bluffs northwest of Hamburg a loess-like talus was seen in which with occasional land snails some broken valves of a unio were noted. Such loess has also been observed by Professor Shimek east of Hamburg and it probably represents material which has been formed comparatively recently. The same may be said of some loess in the vicinity of Glenwood, where ancient potsherds have been found several feet under the surface on low uplands.

The fossil snails of the loess are not quite as numerous as in Pottawattamie county. The collections which the present writer made have been submitted to Professor Shimek, whose report on these and on others collected by himself in this part of the state

*Compare Iowa Geol. Surv. Vol. XI, p. 253.

is appended. In two places vertebrate remains have been discovered. Bones of a mammoth were exhumed from the lower part of the loess at Malvern in grading for the Chicago, Burlington and Quincy railroad. The excavation was made in 1879 on lot 327, at the crossing of First avenue and Railway street. There were three teeth, part of a tusk and two long bones. The other locality is in the southernmost point of the bluffs between Keg creek and the Missouri bottoms, east of Pacific Junction. In grading the railroad some bones of an elephant or of a mastodon were unearthed near the base of the loess. As fossils of the loess must perhaps also be included occasional potsherd and flint implements, which have been noted in the vicinity of Glenwood. They are reported to have been taken out from a few feet below the surface on some upland slopes and ridges and they are of interest as indicating a recent origin of the upper part of the loess deposit.

REPORT BY PROFESSOR B. SHIMEK ON THE FOSSILS FROM THE LOESS OF MILLS AND FREMONT COUNTIES.

Professor Udden submitted six collections of fossils for examination. Three of these are from Mills county, and three from Fremont county. The writer of this supplementary report also collected fossils in several localities in and near Hamburg, in Fremont county. The several lists follow:

1. From base of loess in bluff of Kelly creek, one quarter mile south of Glenwood, Mills county. Professor Udden.

Helicina occulta Say, 1*.
Leucocheila fallax (Say) Try, 1
Bifidaria armifera (Say) Sterki., 1.
Zonitoides arboreus (Say) Sterki., 1.
Pyramidula striatella (Anth.) Pils, 1.
Helicodiscus lineatus (Say) Morse, 2.
Succinea avara Say, 1.
Succinea,† 2.

2. Exposure three miles south of northeast corner of section 31, Oak township, Mills county. Professor Udden.

*These numbers indicate number of specimens collected of each species.

†These collections contain a number of larger Succineas, some of which are certainly *S. ovalis* Say (commonly known as *S. obliqua*) and others quite as clearly *S. grosvenorii* Lea. There are, however, small or broken specimens which cannot readily be separated, and they are here reported collectively as Succinea.

Helicina occulta Say, 1.
Vallonia gracilicosta Reinh. 2.
Bifidaria pentodon (Say) Sterki, 1.
Pyramidula striatella (Anth.) Pils, 9.
Pyramidula shimekii (Pils) Shimek, 2.
Succinea avara Say, 3.
Succinea, 7.

3. Base of loess, Missouri river bluffs one-half mile south of Henton, Mills county. Professor Udden.

Helicina occulta Say, 4.
Polygyra leai (Ward) Pils, 2.
Vitrea hammonis (Ström), Pils 1.
Pyramidula alterternata (Say) Pils, 2.
Pyramidula striatella (Anth.) Pils, 1.
Succinea, 1.

The remaining specimens are from the following Fremont county localities:

4. Terraces (?), base of Missouri river bluff near north line of northeast quarter, section 2, Scott township. Professor Udden.

Polygyra multilineata (Say) Pils, 5.
Zonitoides arboreus (Say) Sterki, 1.
Pyramidula alternata (Say) Pils, 1.
Pyramidula striatella (Anth.) Pils, 1.
Helicodiscus lineatus (Say) Morse, 1.
Succinea retusa Lea, ? 1.
Limnæa humilis Say, 1.

5. Base of Missouri river bluffs, west of Hamburg. Professor Udden.

Helicina occulta Say, 1.
Helicodiscus lineatus (Say) Morse,* 1.
Succinea avara Say, 5.
Succinea, 7.

6. Exposure in northeast quarter, section 6, Washington township. Professor Udden.

Helicina occulta Say, 7.
Vallonia gracilicosta Reinh, 1.
Pyramidula striatella (Anth.) Pils, 4.
Pyramidula shimekii (Pils) Shimek, 1.
Helicodiscus lineatus (Say) Morse, 1.
Succinea avara Say, 2.
Succinea, 7.
A snail's egg appearing like that of *Pyramidula striatella*.

*This appears to be a modern bleached shell.

The writer's collections were made in the years 1890 and 1898 in the immediate vicinity of Hamburg, Fremont county. The several lists, with brief discussions of localities, follow:

7. An exposure in the brickyard east of the Nishnabotna river contained fragments of Unios only one of which, *Obliquaria reflexa* Raf. (formerly known as *Unio cornuti*) was identifiable. The deposit was only a few feet above the river, and showed evidences of redeposition. Two small exposures near the brickyard, and but little higher, contained the following fossils:

Bifidaria pentodon (Say) Sterki, 3.
Pyramidula striatella (Anth.) Pils, 1.
Pyramidula shimekii (Pils) Shimek, 1.
Vallonia gracilicosta Reinh, 1.
Helicodiscus lineatus (Say) Morse, 1.
Sphyradium edentulum alticola (Inger) Pils, 1.
Succinea avara Say, 10.
Succinea, 4.
Limnæa humilis Say, 1.
Unio —— unidentifiable fragments.

As noted, these deposits are but little elevated above the river, and are not typical upland loess.

8. An exposure at the base of the Missouri river bluff northwest of Hamburg. This exposure was but little elevated above the broad Missouri river plain, resembling No. 7 in this respect.

Helicina occulta Say, 14.
Polygyra leai (Ward) Pils, 2.
Leucocheila fallax (Say) Try, 4.
Cochlicopa lubrica (Müll), 1.
Helicodiscus lineatus (Say) Morse, 2.
Succinea ovalis Say (=*obliqua*), 2.
Succinea, 4.
Unio fragments.

9. A great loess-covered ridge extends southward between the Nishnabotna and Missouri valleys, and terminates abruptly in Hamburg. Near its southern extremity, at a point about thirty-five feet above the river plain, near the schoolhouse, an exposure yielded the following fossils:

Polygyra multilineata (Say) Pils, 1.
Polygyra hirsuta (Say) Pils, 1.
Succinea grosvenorii Lea, 3.
Succinea avara Say, 1.
Helicina occulta Say, 3.

10. An exposure at the top of the Hamburg ridge about 150 feet above the river plain. The ridge is fully exposed on the south and west to the winds which sweep across the broad valley of the Missouri river, and its materials in this exposure show a considerable admixture of fine sand. The fossils which were obtained by digging are here listed.

Helicina occulta Say, 5.
Bifidaria pentodon (Say) Sterki, 2.
Vertigo bollesiana (Morse), 3.
Polygyra multilineata (Say) Pils, many.
Cochlicopa lubrica (Müll), 5.
Pyramidula shimekii (Pils) Shimek, 1.
Sphyradium edentulum alticola (Inger) Pils 4.
Succinea, many.

In addition to these numerous other specimens were piled up on the surface. Some of these may be loess fossils, but most of them are clearly modern shells. They are the following:

Pyramidula striatella (Anth) Pils, probably fossil.
Vallonia gracilicosta Reinh, not fossil.
Leucocheila fallax (Say) Try, not fossil.
Helicodiscus lineatus (Say) Morse, probably not fossil.
Succinea grosvenorii Lea, not fossil.
Vitrea hammonis (Ström) Pils, probably recent.
Zonitoides arboreus (Say) Sterki, probably recent.
Quadrula undulata (Barnes) Baker, better known as
Unio plicatus Kust. A well-preserved valve, one and three-fourths inches long, and fragments of another, were found on the surface. They are probably valves of the same young shell. The valve is incrusted in part with calcium carbonate.

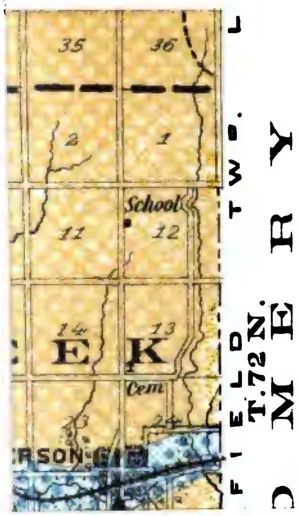
It is interesting to note that these recent species are *all* represented in the loess of the same region, with the exception of the Unio, which, of course, did not live on the ridge, but was brought to it from one of the adjacent streams.

The occurrence of fluviatile bivalves in some of these exposures is of interest. It will be noted, however, that in every case the exposure is low, within easy reach of flooded adjacent streams. Some shells are frequently embedded in ice, and during floods in the spring are deposited above the ordinary level of the stream. Moreover, muskrats frequently carry mussels to some distance from the water. The writer has seen a crow carry a small mussel to a point more than fifty feet above the Iowa river. The presence

of these shells, few in number and at low levels in deposits which have been subject to overflow, adds nothing in support of the theory that the main body of the loess was formed in water. A similar mussel-bearing deposit at Sioux City has been known for some time. At both localities the deposit is unlike ordinary upland loess, and has probably been re-arranged by water. No mussel-shells were found in the collections submitted by Professor Udden. However, in the set marked No. 4, which is from a terrace at the base of a bluff, a Limnæa and a specimen of *Succinea retusa* are found. The first is a pond snail, the second, not satisfactorily identified in its fragmentary condition, a marsh species. Both now live in the region, and neither indicates general aquatic conditions. It will also be observed that one specimen of Limnæa was also found in the brickyard exposure, No. 7, associated with the mussel fragments.

All the remaining species in the several lists are strictly terrestrial, of the usual type found in the loess, and with three exceptions the species now live in the bluff region between Council Bluffs and Hamburg, as the writer has ascertained by personal investigation and as noted, some are now found on the Hamburg ridge. The three exceptions are *Helicina occulta, Pyramidula shimekii* and *Sphyradium edentulum alticola*. These are all upland terrestrial species, now living in other parts of the country, and the two latter belong to the dry western regions. Where any of these terrestrial species show variation from ordinary easterly types, it is of the same charter as that exhibited by the modern shells of the same region. For example, *Polygyra multilineata* as found in loess of the region under discussion, is the small, rather heavy, coarsely ribbed form, often without color-bands and fine revolving lines, which commonly occurs in the west in open or upland country. The Succineas are also of the smaller westerly type. *Vallonia gracilicosta* is a western upland species.

The inevitable conclusion drawn from these fossils is that the deposit in which they are imbedded was formed under conditions not materially different from those which prevail in the same region today. That the amount of material carried by winds is sufficient for the formation of such a deposit was amply demonstrated, not only during the two visits to Hamburg, but upon every



COUNTY
IOWA.

BY

J.A.UDDEN

1903.

one of the numerous summer and autumn excursions which the writer has made to the Missouri river in Iowa and Nebraska. Dust storms which blot out the landscape by the mass of whirling, blinding dust are common, and even ordinary winds carry columns of dust from the sand and mud bars of the Missouri to heights far above the bordering hills. During the low water stage in summer and autumn the bars are of great extent and contribute large quantities of fine materials to the adjacent hills, where they are retained by the vegetation which covers the hills.

In the light of the evidence furnished by the fossils it is useless to search for causes and means of loess deposition which would postulate conditions differing in any important particular from those which now prevail in the Missouri river region.

The Alluvium.—Though the alluvium deposits are extensively developed in the drainage valleys opportunities of studying exposures of their deeper parts are wanting. The material which appears in the stream banks is mostly fine yellow silt, evidently derived mainly from the upland loess, with some sandy layers at distant intervals. Often the upper four or five feet consist of a black muck on the larger flood plains. But the alluvium extends considerably below the beds of the streams and at greater depths contains layers of sand and gravel as well as beds of old soils now buried under from twenty to thirty feet of the more recent alluvium. In the west part of Thurman such an old soil is frequently found in digging wells. On the bottom lands in the East Nishnabotna well makers report going through a few feet of black soil and below this about twenty feet of yellow clay silt. Below this there is some five or ten feet of fine quicksand and about fifteen feet of blue clay, under which is a white or gray sand, often with some gravel. The latter usually contains water. This succession may be regarded as typical of the bottoms of both of the Nishnabotna rivers. In the bottoms of the Missouri river the alluvium is known to have a depth of not far from eighty feet farther north, and it probably has the same depth here. Where the bluffs recede from the river and the bottoms have not been subject to destruction and reconstruction by recent meanders low alluvial fans have in many places been built up by the streams which come down from the uplands and there

may be a gradual rise of the alluvial plain toward the bluffs of as much as thirty or even forty feet. In one of these alluvial fans near the village of Knox charred wood and some animal bones were once found in an old soil at a depth of about twenty-five feet under the present surface.

Calcareous Tufa.—Some heavy deposits of calcareous tufa have been formed in the base of the bluffs of the Missouri. One of these deposits occurs near the county line along the road east and north of Buckingham lake. It forms a bed some five feet thick and lies on a gravelly silt. In places it is impregnated with wad, which makes it almost black. In constructing the road it has been broken up into large blocks which have been thrown aside. The other locality is a little southeast of the center of section 10, Lyons township, Mills county, where large springs issue from under the drift, here resting on the Coal Measures. A mass of coarse tufa eight feet high runs for a distance of about 200 feet along the foot of the bluff. Some tufa was also found in a ravine east of Wabonsie lake and this contains fine imprints of leaves. It is hardly necessary to add that all of these deposits were very recently formed by waters issuing from the drift back of the place where they now lie, and that in some instances they are still forming.

Geological Structure.

If the writer's correlations of the ledges of the Missourian are correct there is a gentle general dip to the south of not more than three feet per mile. Probably there is also a similar dip to the west. The evidence is not conclusive. In some shales in a ravine in the northeast quarter of the northeast quarter of section 24, Tp. 67 N., R. XLII W., two sharp but small folds were observed involving a few feet of the rock in such a way as to produce two overthrusts. These were a few rods apart.

Scorings.

Scorings made by the ice which deposited the bowlder clay have been noted in this territory by Professor Todd. The present writer observed some additional scorings not previously recorded. One locality is near the southeast corner of section 22 in Glenwood township, Mills county, about 150 feet southwest

of the bridge across Keg creek. They are seen on a low ledge of limestone in the west bank of the creek and run S. 12° W. and S. 14° W., with a length of about forty feet. On top of the limestone in the bluffs in sections 10 and 15 in Lyons township, Mills county, scorings are frequent. Their bearings were noted in several places as follows: S. 29° W., S. 34° W., S. 33° W., S. 25° W., S. 29° W., S. 27° W. On a ledge of rock which is now concealed, in the south bank of Spring Valley creek a little south of the center of the south line of section 36 in Rawles township, Mills county, fine planing and scoring was observed many years ago by the quarrymen and some specimens are found on rocks taken from the quarry at this place. The striations are said by a man who worked in the quarry to have a northeast-southwest trend.

A most peculiar instance of scorings on the upper surface of a black shale was observed at a small quarry about one-half mile south of Henton in the base of the bluffs. The shale is the uppermost of the Missourian at this place and is overlain by a discontinuous, thin layer of bowlder clay on top of which loess rests. A finely striated horizontal plane separates the bowlder clay and loess from the shale and the striæ bear S. 7° W., straight for several feet. A hundred feet to the north the same shale is cut by a shearing plane almost as perfectly planed and scored, the striæ running S. 50° W. This plane is gently inclined to the west.

ECONOMIC PRODUCTS.

Building Stone.

Building stone is scarce in this region and most of that used is at present imported. There are nevertheless a few quarries from which considerable rock may yet be taken out. The largest is in section 16, Lyons township, Mills county, in the bluffs of the Missouri river. The limestone ledges at this place have already been sufficiently described. The lower ledges furnish a strong and durable building stone which was formerly extensively quarried and used in the construction of bridge piers and in riprapping embankments of railroads along the river. Several acres of the ledges were removed, but as the face of the

quarry receded the stripping became more expensive and quarrying on a large scale was abandoned several years ago. This illustrates the condition of almost all the quarries in both counties. The most easily worked ledges have been removed and those which remain require heavy stripping before they can be quarried. The sandstone of the Cretaceous south of Henderson is a strong and durable building stone and it seems that some of these ledges might be worked quite inexpensively. At present quarries are operated only occasionally in these counties.

Coal.

The seam of coal which appears in the bluffs east of Lake Wabonsie and in the uplands east of Hamburg is reported as having been twenty inches thick in one exploration pit in section 1, Tp. 67 N., R. XLII W. It is of a good quality and lies near the surface. It does not seem improbable that some workable pockets may be found under the uplands northeast of Hamburg, and possibly also on the west side of the Nishnabotna river, but as the seam lies above the general level of the eroded surface of the Coal Measures it is certain to run out against the overlying drift and be absent on most of the land. As the seam is thin and as most of it has been washed away explorations must be expected to meet with failure in most instances.

Clay Industries.

The production of brick in Fremont county amounts to about four million and in Mills county to nearly two million in a season, eight firms being engaged in this industry in the former and three everywhere the material used. Mr. C. W. Carman, at the latter place, uses a leached shale from the Coal Measures in various proportions with the loess. Mr. T. S. Hall of Glenwood is the in the latter county. Excepting one firm in Hamburg, loess is only maker of bricks used for paving and these are loess bricks, burnt hard and culled from the common. Open kilns are used in all the yards and Missouri coal is the fuel most generally employed. Very little of the product is exported. The detailed statements for each manufacturer are given in the following table.

CLAY INDUSTRIES.

NAME OF OWNER AND LOCATION.	CLAY USED.	HOW DRIED.	OPEN KILNS.	QUANTITY OF PRODUCT —COMMON BRICK.	NUMBER OF MEN EMP'YD.	KIND OF MACHINE.	VALUE. (estimat'd)	REMARKS.
C. W. Carman, Hamburg	Loess and shale..	Shed dried.	5	1,000,000	10	Quaker soft mud.	$5,500.00	Town and country market.
Fred Johnson, Hamburg.......	Loess............	Shed dried.	3	500,000	7	Hand made.	2,750.00	Market: home and other towns.
A. E. and A. P. Brown, Hamburg	Loess............	Sun dried	2	500,000	6	Anderson's Chief	2,750.00	Town and country.
John Johnson, Riverton	Loess......	Shed dried.	3	400,000	6	Hand made	2,400.00	Market: home, country and surrounding towns.
X. Stone, Malvern............	Loess and soil....	Shed dried.	3	800,000	10	Sells.......	6,400.00	Market: home, other towns and country.
John Weatherhead, Tabor. ..	Loess..	Shed dried.	3	600,000	10	Sells..	4,500.00	Town and country.
T. L. Hall, Glenwood	Loess.	Shed dried.	2	850,000	5	Machine ?........	5,950.00	Home market.
J. W. McMullin, Emerson...	Loess wash.	Sun dried	1	200,000	3	Hand made......	2,100.00	Home market.
S. O. Carter, Sidney..........	Loess............	Sun dried	.. ...	3 0,000	3	Soft mud.	2,450.00	Home market.
D. C. Johnson, Sidney.	Loess............	Shed dried.	....	200,000	3	Hand made.......	1,400.00	Home market.
Iowa Institution for Feeble-Minded Children	Loess.	Sun dried..	2	600,000	5	Hand made.......	4,000.00	Used at the institution.
Total.	.. ....	....	24	6,000,000	68	....	$40,200.00	

Water Supply.

On the uplands, which are everywhere well drained, the natural water supply is now becoming more limited than before owing to the general lowering of the level of the ground water. In the base of the loess there is always some seepage, but this cannot be relied upon to furnish a sufficiency for most farmers, and wells are now sunk into the underlying bowlder clay. But this seldom contains sandy strata pervious to water and such wells frequently must be made deep enough and wide enough to catch sufficient seepage from the compact and impervious clay. Occasionally these deep wells go through the drift and draw water from the underlying bed rock. In the northeast part of Mills county there is a sandstone in some wells and these furnish plenty of good water. But over most of the upland the bed rock consists of Coal Measure shales with thin ledges of limestone and on such land even deep wells have proved failures. Deep and wide bored drift wells will probably prove to be most serviceable, and tributary tunnels will no doubt prove useful, where they can be bored out and tiled from the bottom of the main excavation.

On the alluvial bottoms there is always water at moderate depths, varying from ten to fifty feet and driven wells are in general use. Near Riverton an attempt was made some years ago to secure flowing water from shallow wells on the Nishnabotna bottoms, but it resulted in failure, though three holes were sunk to a depth of about 300 feet. A flowing well was unexpectedly obtained near the center of the northwest quarter of section 14 in Anderson township, Mills county. It was made near the foot of the west slope of Mud creek and the water came from a sand under a blue "shale" at a depth of about 200 feet. The head of the flow is forty feet above the curb. The flow was nearly a barrel a minute. It is probable that the sand in the bottom of this well is an outlier of the Cretaceous sandstone.

The conditions for deep artesian wells have been sufficiently discussed by Professor Norton.* Since his paper was published another deep well has been made by the Institute for Feeble Minded Children at Glenwood. Artesian flow can be obtained at a depth of about 2,000 feet on all lowlands not rising higher than about 950 feet above the sea level.

* Artesian Wells of Iowa, Iowa Geol. Surv., Vol. VI, pp. 340-347.

STATICTICS ON PUBLIC WATERWORKS.

LOCATION.	SOURCE OF WATER.	Depth of well.	Number of wells.	Power used.	Head of pressure.	Pumping capacity—gallons per day.	Length of water mains.	No. of hydrants.	No. of taps.	Cost of plant.	When built.
Hamburg	Springs and one well	25 ft.	1	1 steam pump	170 ft.	400,000	1½ miles	25	80	$14,000	1891
Malvern	Alluvial gravel	40 ft.	27 points.	1 steam pump	120 ft.	200,000	2 miles.	15	35	8,000	1892
Tabor	Drift gravel	80 ft.	.....	.....	.....	.....	.....	.	.	....	*
Iowa Inst. for Feeble-Minded Children	Artesian and drift	191-300ft.	2	2 steam pumps.	60 ft.	95,000	¾ mile	12	36	85,000	1896
Glenwood	Artesian	2,014 ft.	1	1 steam pump.	60 ft.	100,000	2½ miles	19	175	15,000	1892
Sidney	Drift seepage.	50 ft	1	1 steam pump	70 ft.	80,000	2 miles	13	21	10,000	.....

*In process of construction.

Sand and Gravel.

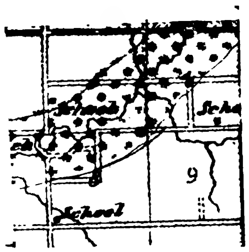
Sand for mortar and plaster is taken mostly from the beds of the streams, where it is by no means plentiful except in the Missouri. An extensive gravel and sand pit was worked for several years by the railroad in the bluffs of the Missouri river near the center of section 32, a mile south of Henton station, but this pit is now abandoned except for local demand. It is a glacial sand which in places has been cemented by infiltration of calcareous material into rock strong enough to be used in small foundations. Another sand pit supplies a local demand in Fremont county. This is located in the base of the bluffs east of Percival, near the center of the west line of section 30, Tp. 68 N., R. XLII W. This sand is rather fine and is probably of a later age than the bowlder clay.

Soils.

The wealth of this region is due chiefly to the excellency of the soil, which is for the most part a porous loess or loess wash, with a deep black humus on all the lowlands. Sandy tracts are almost unknown and only of very limited extent near the channels of the Missouri and Nishnabotna rivers. A few acres of such soil is seen on the south side of the Nishnabotna west of Riverton. In a few places on the upland slopes the red gumbo clay is in evidence, and bakes in dry seasons. The best lands, as being least affected by seasonal variations in rainfall, are the low terrace flats, usually known as the "second bottoms." In dry seasons such land is low enough to draw moisture by capillarity from below and in wet seasons it is high enough and the soil porous enough to allow the superfluous precipitation to sink away into the sandy ground below.

ACKNOWLEDGMENTS.

For aid in the field work in these two counties the author is under obligations to his son, Jon Andreas Udden, who gave valuable assistance the entire season, to Mr. Seth Dean of Glenwood for information relative to that locality and to the old Hamburg Fuel and Mining Company for an opportunity to examine the core from their prospect drilling. His thanks are also due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School

to Professor B. Shimek, who has examined the fossils from the loess and kindly reported on them, to Dr. Samuel Calvin, Dr. Josua Lindahl, Dr. J. M. Clarke and Dr. Schuchert for aid in identifying fossils and to Dr. George L. Smith of Shenandoah for some specimens of coal from the Nodaway vein and for notes on the geology of that region. Dr. E. Schellwein, of Königsberg, Germany, has kindly examined and reported on several samples containing Foraminifera.

GEOLOGY OF TAMA COUNTY

BY

T. E. SAVAGE

GEOLOGY OF TAMA COUNTY.

BY T. E. SAVAGE.

CONTENTS.

INTRODUCTION.

LOCATION AND AREA.

Tama county was named after the Musquakee Indian—Tai-o-mah.* It embraces a beautiful area situated in the east-central portion of Iowa. It lies in the middle row of counties extending east and west and in the second tier to the east of the center of the state. The counties of Grundy and Black Hawk border it on the north and Benton lies on the east. Poweshiek county touches it on the south and Marshall and Grundy form its western boundary.

Tama county embraces an area included by the United States land survey in the townships 82 to 86 north and ranges 13 to 16 west of the fifth principal meridian. It is a rectangle in form, thirty miles in length north and south and twenty-four miles in width. It comprises twenty congressional townships which give it an area of 720 square miles. One of these congressional townships, that in which the the towns of Tama and Toledo are situated, has been divided into two civil townships. Sections 1 to 24 inclusive form the civil township of Toledo, while the remaining sections, 25 to 36, constitute the township of Tama.

A part of this fortunate area lies within the limits of the Iowan drift plain, and furnishes to the agriculturalist a soil unsurpassed in its depth and productiveness by any portion of our fertile state. The southern part of the county is richer in the wealth of forest growth and woodland beauty. The steeper hill slopes and broad valleys where less suitable for constant tillage afford for

*McGee: Eleventh Annual Report U. S. Geol. Surv., p. 313.

grazing purposes conditons but seldom equaled. To the earlier settlers of Iowa this region must have appeared as a happy land in which to found a home. The well wooded southern portion would appeal to the pioneer who had migrated from the timber districts of the east, and would assure to him and his posterity the possibility of an abundance of fuel with which to meet the rigors of western winters, while close at hand stretched the treeless prairie of the Iowan drift plain waiting only for the plow and the seed to reward the husbandman with bountiful harvests. Although there are but few exposures of indurated rocks over this region, yet to the geologist the county presents features of more than usual interest for the reason that the soils of the area have been derived from two different ice invasions, separated from each other by an exceedingly long interval of time; while the well borings and excavations reveal the presence of a third drift sheet underlying and very much older than either of the other two.

EARLIER GEOLOGICAL WORK.

In his description of the range of the Carboniferous limestone in Iowa, published in 1852, D. D. Owen mentions the exposures along the Iowa river on the western border of Tama county. He also describes the symmetrical mound-like form of some of the outliers of the limestone in this region, and figures one which doubtless represents what is known locally as the Devil's Anvil, near the Tama and Marshall county line. Professor Owen included the southwest corner of the county within the limits of the coal fields of the state.*

In his report on the Geology of Iowa in 1858, Professor James Hall notices the meagreness of the rock exposures over the surface of Tama county, and refers to one or two outcrops which he found near Butlerville, or Indian-town. In this connection he pays a tribute to the excellent quality of the soil over the particular region under consideration.†

Professor C. A. White, State Geologist of Iowa from 1866-1869, devotes two or three pages in his report to a description of the rocks and the quarries which are found near Le Grand. The greater part of this description might with almost equal propriety

*Owen: Geol. Surv. of Wisconsin, Iowa and Minnesota, pp. 98, 99, 101 and 102.
†Hall: Geol. of Iowa, Vol. 1, pt. 1, pp. 266-268.

be applied to the exposures in Tama county about one mile farther down the Iowa river.*

Tama county is included within the area of northwestern Iowa, the Pleistocene history of which has been so beautifully written by W J McGee.† He refers to the exposures of the Kinderhook limestone along the Iowa river between Marshall and Tama, and mentions the wide character of the flood plain of the river as it meanders through the county. He speaks of the deep covering of loess over the hills west of Tama City and gives a few sections or wells within the area.

In 1898 Mr. H. R. Mosnat published a report on the artesian wells of the Belle Plaine area, in which area the southeastern portion of Tama county is included. Mr. Mosnat gives a general description of the deposits associated with the water bearing bed and mentions a number of wells put down within the borders of the district under discussion.‡

Two years ago the present writer published a short paper on an exposure of pre-Kansan drift in Tama county.§

PHYSIOGRAPHY.

TOPOGRAPHY.

General Description.—Tama county embraces a region of extensive level or undulating prairies unbroken by branch or gully; a region also of well matured drainage where deep dissecting ravines are bordered by high loess covered hills and abrupt slopes; a region where the smooth unsculptured plain of the Iowan drift gives place to the trenched and furrowed surface of the Kansan. The line of surface contact along which these two drift sheets meet is indicated by a border of irregular hills; the drift of which they are largely composed is of Kansan age while the caps of sand or loess were probably deposited during the time the Iowan ice prevailed and stood at its maximum southward extension.

*White: Geol. of Iowa, Vol. II, pp. 312-314.

†McGee: Pleistocene History of Northeastern Iowa, Eleventh Ann. Rep. U. S. Geol. Surv. pp. 409, 428, 432, 470 and 528, 1889-1890.

‡Mosnat: Iowa Geol. Surv., Vol. IV, pp. 523-562.

§Savage: Proc. Iowa Acad. of Sciences, Vol. VIII, pp. 275-278.

In some places where a lobe of the Iowan ice advanced farther south than the main sheet the mantle of drift which was left is so thin that the characteristic features of the Iowan plain were not impressed upon the area. Here we have a mixed or hybrid topography where the subdued hills of Kansan drift, in many cases covered with beds of sand or loess twenty to twenty-five feet in thickness, look down upon valleys choked and filled with glacial debris in which are found drift and granite bowlders of the Iowan age.

Besides the above mentioned topographic features the very wide flood plains through which the most of the larger streams of the county flow, present their characteristic level type of surface.

The Iowan Drift Plains.—A sinuous line of hills which marks the southern margin of the Iowan drift sheet enters on the west side of Tama county about one and one-half miles north of the Iowa river, near the southwest corner of section 30, Carlton township. From this point it trends southeast for about one mile, to the eastern part of section 31, then passes north for two and one-half miles. Near the southeast corner of section 18 these low

Fig. 19. Margin of the loess Kansan area in Carlton township, showing the ridges which mark the border of the Iowan drift plain.

ridges which constitute the Iowan moraine trend eastward, reaching Deer creek about one-fourth of a mile south of the corporation limits of the town of Garwin. From this point they trend towards the northeast, across Howard township, entering Carroll township near the southwest corner of section 6. Thence they continue so nearly eastward that where they leave section 10, four miles further east, they have scarcely passed one-mile to the south. The border of hills now bends to the southeast and continues parallel with the channel of Salt creek passing across section 11 and the southwest corner of section 12, then drops southward for over a mile, leaving the township about one-fourth of a mile south of the northeast corner of section 24. For a distance of one and three-fourths miles it continues southeast. It then bends west for one mile along the north side of section 31; then turning to the southeast it crosses section 31 and the southwest corner of section 32, entering York township about the middle of the north side of section 5. Continuing southeast one-half mile and then east for three quarters, it bends southward for a distance of two miles and one-half. It then trends southeast for about one mile; bending south one mile further it passes nearly due east for three-quarters of a mile and then bends to the southeast, continuing parallel with the valley of Salt creek across section 26, the northeast corner of 35 and the southwest corner of 36, entering Salt Creek township about one-half mile west of the town of Irving. It continues in a general southeast direction passing out of Tama county near the southeast corner of section 1 of Salt Creek township.

All of that portion which lies to the north of the line traced above, embracing about one-half of the area of the county, is a part of the extensive plain of Iowan drift which stretches away to the northward beyond the limits of the state. This surface is generally level, or but slightly undulating. The drainage is but imperfectly developed over most of the area. The broad, shallow channels along which the excess of water is discharged head in seepy sloughs or swales, and the most of the smaller streams have scarcely cut a definite bed in which their waters are confined.

The northern portion of the county is crossed by Wolf creek. This is a stream of considerable size which has cut its channel to

a depth of thirty or forty feet into the Kansan drift. It flows in an ancient valley which was excavated before the invasion of the Iowan glaciers. The amount of drift materials that was carried by the Iowan ice was not sufficient to completely bury the old channel, and so, when the ice retreated, the waters once more became established in this pre-Iowan bed. Owing to the very thin mantle of Iowan drift which was left over this region the waters of Wolf creek and its tributaries have been able to remove the greater part of the Iowan covering from the immediately adjacent lands. Such erosion has occurred whenever a slope of a few degrees has been developed, exposing along the roadsides and in the banks of the ravines the older sheet of Kansan till.

There is thus a belt, two to four miles in width, bordering Wolf creek, which lies within the area of the Iowan drift but which presents the bold forms of water sculpture so characteristic of the Kansan plain. The physical features which this strip presents are but a forecast of the fate which will eventually overtake all of the level prairie country as the drainage becomes more and more perfected, unless there intervenes some counteracting force to check the slow but ceaseless work of the stream erosion.

From the main sheet of Iowan drift above described a tongue shaped lobe having an average width of about six miles, extends southward for a distance of eight or nine miles, reaching one mile below the city of Toledo and within two miles of the Iowa river. This extension may be called the Toledo lobe of the Iowan drift. It is bordered on the west, from the point where it leaves the main Iowan drift sheet about the middle of the south half of section 14 of Carlton township down to near the middle of section 21 of Toledo township, by the hills which form the west bank of the valley of Deer creek. From the latter point the irregular ridges which mark the margin of the lobe trend to the southeast for one-half mile and then eastward, continuing in an undulating line near the north side of sections 27, 26 and 25 of the township of Tama. They enter Otter Creek township not far from the southwest corner of section 19. From this point they trend in a northeasterly direction across the southern portion of section 19 and bending further to the north they cross the northwest corner of section 20. Otter creek passes through a gap in these hills near the southwest

corner of section 17. From here the ridges extend in a general northerly direction, bending alternately eastward and westward, near the west side of sections 17, 8 and 5. They enter Carroll township near the southeast corner of section 31. Continuing northward with a slight inclination toward the west for a distance of five miles, they merge into the morainic hills of the proper Iowan drift plain near the southwest corner of section 6.

This Toledo lobe covers the greater portion of Howard township, a small corner of Carlton, a little more than the east half of the township of Toledo and a narrow strip from the west side of the townships of Otter Creek and Carroll. It is about four and one-half miles in width at the southern extremity and nearly eight miles across at the north where it leaves the main sheet. It embraces an area of over 31,000 acres.

Over the southern portion of this lobe the surface is that of a billowy prairie. The elevations seldom exceed twenty feet above the broad channels of the streams. A thin covering of Iowan drift occurs over the lower lands and in places is found even on the tops of the subdued hills. The drift is of the typical Iowan character. It is yellowish brown in color. The iron which it contains is not fully oxidized and the calcareous matter is not leached from the surface. It carries but few pebbles or small bowlders as compared with the Kansan and of these there is but a small percentage of the dark colored trap or greenstones.

Over this region the Iowan drift is usually concealed beneath a covering of loess which varies from a foot or two to several feet in thickness. Such a loess covered bed of Iowan drift is well exposed along the roadside between sections 18 and 19 of Otter Creek township, and again about the middle of the line which separates sections 23 and 26 of Howard township. The presence of loess overlying Iowan drift is not unique over the state but this is not its usual mode of occurrence. In central and southern Iowa the deeper beds of loess are found covering Kansan drift at no great distance from the Iowan border. It seems probable that then as now loess materials were deposited on the leeward side of obstructions to dust-laden currents of air, or where in the path of such winds the soil was covered with vegetation which would serve to catch and retain the dust particles that fell upon it. How-

ever, the distribution of loess over this portion of the state would indicate that during the time when the Iowan ice prevailed, the conditions were exceptionally favorable for its deposition and that probably the source of much of the material might have been the super-glacial silt from the Iowan ice sheet itself.

Very often the deposits of Iowan drift are found in the valleys while till of Kansan age composes the hills, emerging at the surface along the upper part of the slopes. Examples of hills with Kansan drift exposed at the top and having Iowan materials flanking the base may be seen in the northern part of section 35 of Howard township, and along the middle line of section 21 of the same township.

The Iowan ice which pushed down over this area carried quite a large number of light-colored, granite bowlders. These bowlders are usually from four to eight feet in diameter but individuals ten to twelve feet in length are not rare, while one specimen was seen with a long diameter of about thirty feet. Bowlder strewn fields, some of the rocks of large size, may be seen about eighty rods south of the Toledo and Cedar Rapids road, one in the eastern part of section 23, and another in the western part of section 24 of Toledo township. Occasional bowlders dot the surface along the courses of streams over all of this region. They are seldom found on the higher points but seem to have been left during the process of the melting of the ice that carried them, either on the lower flanks of the slopes or along the beds of the streams.

The topographic features of an area across the middle portion of this lobe are bolder. The tops of the hills stand in many places forty to fifty feet above the valleys. The contours are quite sharp and the slopes are steep. The irregular character of these sand or loess capped hills resembles very closely the ridges which are found around the margin of the Iowan drift plain. Even here, however, the stream channels choked and clogged with aqueo-glacial debris, the occurrence of Iowan drift near the base of the hills, and the presence of large, light-colored, granite bowlders along the valleys, bear indubitable testimony to the former presence of the Iowan ice sheet. The axes of these hills are composed of Kansan drift, but their tops are usually covered with sand or

Fig. 20. View showing the topography of the Toledo lobe in the edge of the hills which cross the central portion of this extension of Iowan drift; showing also a large bowlder of Iowan age stranded near the top of one of the hills. The Iowan bowlders are usually found only at or near the foot of the hills. About one and one-half mile northwest of the county poor farm, Toledo township.

with loess, often to a depth of from fifteen to thirty feet. A short distance south of the Monticello church in section 33 of Howard township, the road has been cut through a bank of loess, exposing a depth of about fifteen feet, while in the valley a short distance away there may be seen a bed of Iowan drift. The loess at this place is very fossiliferous, containing numerous individuals of species of Polygyra, Succinea, Pupa and other common genera. Examples of sand covered hills over this area are numerous, but typical places have been already cited.

The peculiar topography of the Toledo lobe, the presence of loess overlying the Iowan drift, together with the very scant amount of material that the Iowan ice sheet left over its surface would seem to indicate an unusual episode in the history of the Iowan ice action. The phenomena which it presents lend themselves to the following interpretation. During the early stages of the extension of the Iowan glacier a narrow lobe of ice was pushed southward beyond the main body over the deeply eroded Kansan

surface, covering the area outlined as the Toledo lobe. For some reason the pressure from behind soon became insufficient to keep up the movement over this lobe and the ice which covered the region became dead, and gradually melted where it came to rest. As the glacier moved slowly over the old Kansan surface, the stones which were held fast along the bottom of the ice would form instruments of attrition of the most effective kind. The materials on the tops of the hills, even though frozen solid, could not but yield rapidly to this grinding action of the ice. The debris worn off from the higher points would be pushed over into the valleys to the leeward of the advancing ice sheet. In this manner the surface inequalities would gradually be reduced both by the constant wearing down of the greater elevations, and by the no less constant filling of the valleys with the materials removed from the tops of the hills. Owing to the short period during which the flow of ice continued over this surface, the tops of the Kansan hills were not subjected to the powerful abrading action of great masses of moving ice for so long a period as were those where the flow continued for the whole time during which the Iowan ice prevailed. As a consequence the pre-Iowan surface here was not planed down to the same extent as it was over the area covered by the main sheet of the Iowan drift.

The generally smooth character of the Iowan drift surface is probably due more to the leveling action of thick masses of ice moving over the region than to the amount of materials transported from great distances which the ice left as it retreated. The Iowan ice did not generally carry such a large amount of drift and debris as the Kansan, as is witnessed by the comparatively thin sheet of materials which is usually found covering the Kansan drift over the main Iowan plain. However, it is probable that the small quantity of ice which melted over this lobe would be one good and sufficient reason for the unusually thin mantle of Iowan materials that is found over its surface.

The cause or causes which resulted in the early cessation of the flow of ice over this lobe did not produce their full effect at once. The movement probably ceased quite suddenly over the southern half of the area, but its withdrawal from the northern portion was accomplished much more slowly and at a much less

uniform rate. A halting in the retreat of the ice near the central portion of the lobe, its line of lower limit receding but very slowly through a long period of time, would result in the accumulation around its margin of deposits of sand and loess by the overwash of materials liberated from the melting ice and by the action of winds sweeping over the surface of the ice sheet and laying down their load to the leeward of its margin.

As a consequence of such deposition the Kansan hills immediately around the border, which had been leveled down to some extent by the ice moving over them, were built up to a height twenty to thirty feet above the more elevated points in the southern portion of the lobe. During this time, also, much of the fine-grained loess materials gathered up by the winds would be carried out some distance beyond the margin of the ice, and thus the southern portion of the lobe would receive a mantle of loess above the Iowan drift which had been previously deposited over the area. When the ice melted there was left the belt of sand or loess crowned hills, one-half mile to a mile in width, which forms so conspicuous a feature across the north-central portion of the lobe.

Some time before the entire withdrawal of the Iowan glacier from the county, the flow of ice ceased over the northern portion of the lobe, the margin retreated to about the same distance southward as that of the main body of the Iowan ice. Along this border a new series of ridges was formed, but the width of this belt is less than that of the one which crosses the central portion of the lobe. The individual ridges are also lower and less conspicuous. Pleasant Hill church, situated about the middle of the south side of section 2 of Howard township, is located on one of the ridges of this moraine.

After the retreat of the ice from the Toledo lobe and probably before the entire withdrawal of the Iowan sheet from this portion of the state, a deposit of loess was laid down in places over the northern portion of the area under consideration.

With this deposit and the retreat of the ice, the stage of the Iowan ice invasion was closed. From that time, so long ago when measured in years yet so recent from a geological point of view, the forces of weathering and erosion have modified but

slightly the topographic forms of its surface, adding only the last touches to the features which the region presents today.

A third body of Iowan drift occurs in Tama county on the south side of the river. This area is an extension eastward of the Iowan drift plain from Marshall county. Its northern margin follows quite closely the Iowa river bluff for a distance of over two miles, reaching within one-half mile of the towns of Butlerville and Montour. From here it stretches away to the southeast across sections 33 and 34 of Indian Village township and passing across sections 2 and 12 of the township of Highland it extends eastward about one and one-half miles into the township of Columbia. The southern margin of this extension follows westward near the north side of Richland creek to about section 23 of Highland township where this body of Iowan ice merges into a southern area which is bounded on the north by the valley of Richland creek and which extends eastward to the southeast corner of Columbia township. This area of Iowan drift stretches away southward into the county of Poweshiek. It is probable that the body of Iowan drift south of the river was a continuous area and that the seeming division which appears along Richland creek is due to the removal of all traces of the Iowan deposits by the erosion of that creek and its affluents in this particular region.

The topography of this Iowan drift plain is somewhat similar to that of the southern portion of the Toledo lobe. The hills are subdued but not effaced. The stream channels are obstructed but not filled to such an extent as to prevent effective drainage. There are no great surface inequalities over the area, the tops of the hills usually standing not more than twenty or twenty-five feet above the valleys. There are fewer bowlders left over this region than occur over the Iowan areas north of the river. However, a few individuals of large size may be seen about the middle of the line which separates sections 26 and 27 of Highland township and others again near the southwest corner of section 29 and the southeast corner of section 30 of Columbia. It would seem as if the Iowan ice sheet which spread over this portion of the county must have been exceedingly thin; that its flow continued but a very short time, and that it carried but a

scanty amount of detritus of any kind. The hill slopes in numbers of places expose the oxidized Kansan drift overlain with a mantle of loess; almost the whole of this area being loess covered. The word mantle is an appropriate term as applied to the loess. Wherever it occurs in the county it forms a cloak or blanket, usually thin, which conforms in almost every case to the preexisting inequalities of the surface over which it lies. Good exposures of typical Iowan drift are here exceedingly rare. However, the hills are not so high, the contours are not so sharp and the stream channels are not so open nor so deep as they are over the typical areas of Kansan drift. The occasional large bowlders of gray granite which sentinel the drainage courses are added witnesses to a transient visit of the Iowan ice.

The Kansan Drift Areas.--On the north side of the Iowa river and to the west of Salt creek a body of Kansan drift extends northward to the margin of the Iowan drift plain. The area is nearly cut in two by the southward extension of the Toledo lobe above described. The topography of this region is exceedingly

Fig. 21. View showing the topography of the loess Kansan area near the southern portion of Tama county.

irregular and its forms have been molded by the action of long continued erosion. The surface is dissected in all directions

with an intricate system of drainage channels. The numerous streams, each with its series of pinnately branching tributaries, have carved the entire region into alternating ridges and ravines. The uplands are narrow. The hills are high. Their tops are crowned with a deep deposit of loess which heightens the inequalities of the surface. The slopes are steep as is usually the case when deeply loess covered districts are subjected to strong erosion. The smaller stream channels are sharply angular and the forces of erosion are energetic at the present time. From the west portion of this area, a narrow strip of Kansan drift, varying from forty to eighty rods in width, extends northward along the west bluff of the valley of Deer creek for a distance of about five miles. This peculiar belt is typical Kansan in character and for some unknown reason was avoided by the Iowan ice which came down on either side.

The hills which form the north bluff of the Iowa river valley are in many places covered with sand. These deposits are probably in the nature of dunes, the materials having been gathered up by the winds as they swept down the broad valley of the river. Examples of such hills occur along the river bluff a few miles east of Chelsea and again a short distance east of the town of Gladstone. In the western part of the county, the sand hills are replaced by loess capped bluffs. Such deposits appear about one and one-half miles east of Tama. At this place in a loess bank about twenty feet in depth Mr. Bentley obtains clay for the manufacture of brick and tile. Several miles farther up the river, along the south side of section 13 of Indian Village township, beds of very fossiliferous loess crown the bluffs which overlook the broad valley opposite the town of Montour.

On the south side of the river the Kansan drift is also overlain by a blanket of loess. Deposits of loess and till of Kansan age constitute the superficial materials over all the the southern portion of the county east of the Iowan area above described. The topography of this region resembles in a general way that of the Kansan drift area lying to the north of the river. Rounded, irregular knolls and open, sharp ravines alternate in almost endless succession. The land features are mature and long continued

erosion has intersected the region with such a network of stream channels that the level upland areas are few, scattered and of small extent. The beds of loess are not quite so deep as on the north side of the river, but here also frequent deposits of loess and sand cap the bluffs which form the south wall of the valley of the Iowa river.

Stream Flood Plains.—The valley of the Iowa river which passes diagonally across the southern portion of the county has an average width of more than two miles. Over this broad plain the river meanders from side to side in a series of broad, swinging curves. Cut-offs have been made in the past and ox-bow lakes occur at a number of places over the plain. A good example of such a curved lake may be seen a short distance above the town of Montour, and several others occur in Salt Creek township below the town of Chelsea. The river swamp is not perfectly drained and shallow marshes are not infrequent over the area at some distance from the river. The bed of the river is but twelve or fifteen feet below the level of the river swamp so that the whole plain is subject to inundation during periods of great flood, such as occurred in the summer of 1902.

The river is bordered throughout almost its entire distance in the county by steep bluffs forty to seventy feet in height. These hills are usually composed of Kansan till capped with a bed of loess or sand. Ledges of indurated rock outcrop in the banks only for a short distance in the western part of its course after it enters from Marshall county.

Each of the larger creeks flows in a broad alluvium covered valley one-half mile to a mile in width, which seems entirely out of proportion to the size of the stream which it accommodates. These valleys, like that of the Iowa river, were probably excavated in preglacial times. They are guarded by hills of drift whose tops usually overlook the plain from a height of forty or fifty feet.

The following elevations taken from Gannett's Dictionary of Altitudes in the United States will give the height above sea level of some of the principal places in the county.

	ELEVATION IN FEET
Berlin	1,056
Gladbrook, Chicago & Great Western railroad	949
Gladbrook, Chicago & North-Western railroad	945
Garwin	792
Toledo, Chicago & North-Western railroad	847
Toledo, Weather Bureau	856
Tama, Chicago & North-Western railroad	820
Tama, Chicago, Milwaukee & St. Paul railroad	827
Potter	863
Le Grand	933
Montour	845
Gladstone	835
Vining	865
Chelsea	789
Elberon	844
Dysart	968
Traer	916
Dinsdale	928

It will be noticed in the above table that the most of the places mentioned from the south and west sides of the county are situated on low bottoms, as the flood plain of the Iowa river and of Deer creek; while most of those given from the north and eastern portion of the area are located on the uplands of the Iowan drift plain.

DRAINAGE.

From a consideration of the table of elevations it will be seen that the highest portion of the county is in the northwest corner and the lowest part is in the southeast. The difference in the altitude between these points is 267 feet. The surface over the northern portion of the county slopes gently towards the east while in the central and southern portions it is inclined towards the south as well as east. As would be expected the streams of the area follow the direction of the slope, conforming in a general way to the normal direction of flow of the rivers of eastern Iowa.

The surface of the county is fairly well drained, even over the more level portions of the Iowan drift plain. The streams belong to two principal drainage systems, the Cedar river and the Iowa. The divide passes east and west across the central portion of Spring Creek township, dipping a little south of the

middle of Crystal and thence across nearly the central portion of the townships of Perry and Clark. The town of Dysart stands on the south edge of this watershed. Cedar river receives all of the excess of water which falls upon the surface north of the divide, draining almost one-third of the area of the county. The Iowa river is the master stream of all of the central and southern portion of the region under consideration.

The Iowa River.—The Iowa river enters Tama county from Marshall near the northwest corner of section 6 of Indian Village township. It holds a general southeasterly course winding diagonally across Indian Village township and the township of Tama, the northeast corner of Columbia, the north half of Richland and the central and southern portion of Salt Creek. It leaves the county about the middle of the east side of section 36 of the latter township. Following all of its numerous curves and zigzag windings, the waters of the Iowa river flow for a distance of about fifty-five miles within Tama county. From the north it receives tribute from Sugar, Deer, Otter and Salt creeks, while Raven, Bennett and Richland creeks flow into it from the south.

For the first six miles after entering the county the curves of the river have deflected the current against the opposing banks, cutting them away at intervals so far as to expose ledges of Kinderhook limestone in the bluffs which border the valley. During all of the rest of its course the river meanders in a broad valley which in preglacial times was excavated in the Lower Carboniferous limestone. Wells which have been bored over this broad flood plain indicate that the preglacial channel was cut down 175-200 feet below the bed of the present river. This ancient channel was filled with drift brought down by the pre-Kansan and Kansan ice. The present river has cut a valley into the Kansan drift two miles in width, to a depth of forty to seventy feet below the general level of the uplands. The width of the preglacial valley has not been determined as in no place along this part of its course have the bordering ledges of rock been exposed.

Wolf Creek.—Of the streams of the county, Wolf creek is second in size only to the Iowa river. It is the major stream of all of the northern portion of the county. It rises in the gullies and

sharp trenches which have been graven into the surface of the eastern portion of Marshall county. It passes across the northern part of the townships of Spring Creek, Crystal and Perry. Thence bending to the northeast, it crosses the southeast corner of Buckingham and continues eastward near the central portion of Geneseo township. It leaves the county about the middle of the east side of the latter township, a short distance before it makes the more abrupt turn northward to meet the Cedar river. That part of its basin which is included in Tama county embraces an area of about 225 square miles. This stream follows along very close to the south side of its basin. It receives but a few short, insignificant affluents from the south, while the streams which pay tribute to it from the north are much larger, more numerous and much more widely branching. While lying wholly in the Iowan drift plain, Wolf creek is an excellent example of the eastward flowing streams which have developed one sided basins; the major stream having cut its channel close to the south side of the area which it drains. McGee noticed that many of the eastward flowing streams of the "loess drift" portion of the state presented this peculiarity, and, as applied to such streams in Poweshiek and Iowa counties, he suggested the following explanation.* He considers the drainage systems of the "loess drift" area to be determined by a number of planes the north rim of each being sharply uptilted and from this ridge the plane inclines southward in a long gentle slope; the east flowing waterway in each case being located along the foot of the gently inclined, southward slopes of the plane; the steeper northward facing slope of the stream basin being the shorter and more sharply sloping front of the next southward extending, gentle incline.

Professor Calvin thinks, however, that these unsymmetrical basins might have been developed from one original gently sloping surface drained by eastward flowing streams, which basins might in their early history have been symmetrical. He shows that the slopes which face the north would suffer much less than those on the opposite side of the channel from the alternations of freezing and thawing and the consequent effects of erosion in

*McGee: Pleistocene History of Northeastern Iowa, Eleventh Ann. Rep. U. S. Geol. Surv. p. 412-413.

early winter and spring. These northward facing slopes would also be less affected by summer droughts which tend to check the growth of vegetation and to render the surface more pulverulent and so more easily attacked by dashing rain storms. Thus as the channels of the streams became deepened the north side of the valley would recede more rapidly than the south. The south facing slopes would slowly become more gradual than those which faced the north and the streams on this side would cut back into the highlands more readily and at a more rapid rate, robbing the secondary streams developed on the south side of the adjacent northern drainage area. In this manner as the drainage basin became more mature it gradually became unsymmetrical and was converted into a sloping plane with the master stream along the southern margin at the foot of a shorter and steeper slope which faced the north.*

Whatever the explanation may be, it is certain that here in Tama county the present streams are following more or less per-

Fig. 22. View looking west across the valley of Deer creek, showing the bluffs which form the western border of the valley and which mark the western margin of the Toledo lobe of Iowan drift, Toledo township.

fectly the old channels of a drainage system which was impressed upon the area before the invasion of the Kansan ice sheet,

*Calvin: Iowa Geol. Surv., Vol. VII, p. 57

and, in most cases, valleys which were formed before the beginning of the Glacial epoch.

Deer Creek.—Deer creek rises among the low, rounded swells of the Iowan drift plain in the southern portion of the Spring Creek township. It follows a general southeasterly direction across Carlton township, the southwest corner of Howard and through Toledo reaching the river in the south part of section 34 of the township of Tama. It flows in a broad valley one-half to three-fourths of a mile in width, the early history of which dates backward into preglacial times. On the east this valley is bordered by the gentle slopes of the Iowan drift plain while on the west the bluffs of Kansan drift rise bold and steep to a height of forty to fifty feet above the bed of the stream. Through numerous gaps in these bluffs the waters of small streams find

Fig. 28. View from the bluff on the west side of the valley of Deer creek, looking east across the valley and over a portion of the Toledo lobe. Showing the topography of the western portion of that area in Toledo township.

their way down to the creek from the uplands. From the east —the side of gentle slopes—a number of affluents eight or ten miles in length pay tribute to this stream, among them Pin, Crystal, Pleasant, Jordan and Minnow creeks, while from the west, a very much older surface, there are numerous short

streams but not one of sufficient size to merit a name. The basin of Deer creek is one-sided but its lack of symmetry is probably due in part to the fact that the west facing slope was leveled by the Iowan glacier, while the east facing bluffs received the deposits which were laid down around the margin of the Iowan ice.

Salt Creek.—Salt creek is the largest tributary to the Iowa river from the north within the county. Its branches rise in the Iowan drift plain, near the divide, in Crystal, Perry and Clark townships. Its basin drains an area of about 180 square miles in the east central portion of the county. As in the case of the Deer creek valley, Salt creek is bordered on the west by abrupt bluffs of Kansan drift, which, at the same time, mark the western margin of the Iowan drift area in that portion of the county. To the east the Iowan plain stretches away in gentle undulations across the borders of Benton county. Like Deer creek also this stream follows close to the west side of its unsymmetrical basin. This one-sided character is probably due to the same causes which produced a like effect on the basin of Deer creek. Like Deer creek again, this stream flows in a channel carved in the Kansan drift which fills a preglacial valley of much greater size. it reaches the river near the east side of section 36 of Salt Creek township.

Otter Creek.—Otter creek is a small stream which rises in Howard township within the area of the Toledo lobe of Iowan drift. It passes downward across the northeast corner of Toledo township, through Otter Creek township and across the northeast corner of Richland, joining the river not far from the center of section 21, of Salt Creek township. Its basin embraces an area of about eighty square miles, including the greater part of Otter Creek township and a small corner of the townships of Howard, Toledo, Richland and Salt Creek.

Sugar Creek.—Sugar creek rises in the northeast corner of Marshall county. It is not more than a dozen or fifteen miles in length. It flows with the usual number of zigzag curves in a general southeast direction, reaching the river near the west side of section 9 of Indian Village township. The chief character in which this stream differs from all others in the county is its

youthfulness. Its valley is quite wide, but not to be compared in width with that of Bennett or Raven creeks—small streams which are no larger than Sugar creek. Then, too, it is still cutting at its banks and its bed. Ledges of limestone are exposed in the bluffs for some miles along the lower course of Sugar creek, a phenomenon to be seen along no other creek in the county.

Richland Creek.—Richland creek is the largest tributary to the Iowa river from the south within the county. Some of its branches rise near the western side of Richland township and others have their source in the northwest corner of the county of Poweshiek. The creek flows nearly due east for a distance of twenty miles—not considering the curves and bends in the channel—finding the river near the west side of section 13 of Richland township. Its valley is one-half to three-fourths of a mile in width and is covered with a deep, dark colored mantle of alluvium. The channel is bordered by hills of drift forty or fifty feet in height. Its basin is very narrow as compared with its length. The near presence of the Iowa river on the north has probably prevented the development of such a long slope on that side of the basin as is usually found in the basins of eastward flowing streams in this portion of the state.

Bennett and Raven Creeks.—Besides Richland creek, the only streams of any considerable size which render tribute to the Iowa river from the south are Bennett and Raven creeks. These streams drain the northern portion of Highland township, the southeast corner of Indian Village and the southwest corner of the township of Tama. They are not more than eight to ten miles in length, yet they occupy wide valleys either one of which would be sufficiently large to accommodate the waters of the Iowa river.

In connection with all of the larger streams of the county the one thing which, again and again, strikes the observer with surprise is the great age of the valleys in which they flow. This extreme age is indicated by their great width and also by the absence of any rock ledges exposed in their bordering banks. It is a significant fact that each of these creeks rises within the Iowan drift plain, and it is very probable that during the melt-

ing of the Iowan ice these channels carried a much larger volume of water than they do at present.

History of the Drainage.—The channels of the present drainage system were probably outlined, for the most part, before the advent of the Pleistocene period. Wells which have been put down over the flood plain of the Iowa river penetrate to a depth of 170 to 230 feet before they reach the indurated rocks.

Along the lower course of Deer creek such borings indicate the presence of a channel 157 feet deeper than the bed of the present stream while in the southern portion of Spring Creek township there are exposed along one side of its valley bordering bluffs of oölitic limestone to a height of ten or twelve feet.

Near the southeast corner of Otter Creek township a well put down on the flood plain of Otter creek was bored to a depth of 200 feet before reaching indurated rocks. Wells put down along the valley of Salt creek penetrate to similar depths before encountering the layers of limestone.

Mr. Mosnat* has shown that the depth and distribution of the flowing wells of the Belle Plain area and the succession of deposits which they penetrate would indicate the presence of a deep valley excavated in the Lower Carboniferous limestone having a width of four to six miles and a maximum depth of 340 feet at Vining and 228 feet at Chelsea. Well borings show the presence of this old channel from a few miles north of Vining down to the southeast corner of the county. It passes beneath Belle Plaine and on southeast into Iowa county as far as the town of Ladora.† This area embraces the more eastward extension of Kansan drift north of the Iowa river; and thus the portion of the county where now the hills stand highest, in preglacial times was the lowest and was occupied by the valley of a large river. The bottom of this valley contains drift of pre-Kansan age which is overlain by a deposit of Aftonian gravels, which bed, in turn, is deeply covered with Kansan drift. These Aftonian gravels constitute the water bearing layer in this portion of the county. At Vining wells are sunk to a depth of 250 feet below the tops of the hills before reaching the bed of gravels, while in the

*Mosnat: Iowa Geol. Surv., Vol. IX, pp. 523-562.

†Ibid, p. 524.

northern part of Otter Creek township a well has been sunk to a depth of 370 feet before the indurated rocks were encountered. It seems probable that in preglacial times this old valley carried the major stream of the region; and that to this river the streams which then occupied the channels of the Iowa river, Richland, Deer and Otter creeks rendered tribute.

STRATIGRAPHY.

General Relations of Strata.

The indurated rocks which are exposed in Tama county belong to but one system of the Paleozoic group. They outcrop only along the middle portion of the western side of the area. To the north, east and south they are buried beneath a covering of drift which in some places is more than 360 feet in depth. It is probable that the rocks which immediately underlie the drift in the northeastern portion of the county are of Devonian age. There are no exposures, however, by which this presumption may be verified, but the first rocks which are encountered to the north and east belong to that system.

The superficial materials contain a record of the desolating action of three different invasions of ice. Each glacial period was followed by a milder interval of long duration during which the surface was clothed with vegetation and peopled with life very much as it is today.

The following table shows the geological formations which are known to be present in Tama county.

TABLE OF FORMATIONS.

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Recent.	Alluvium.
		Glacial.	Iowan.
			Kansan.
			Aftonian.
			Pre-Kansan.
Paleozoic.	Carboniferous.	Pennsylvanian, or Upper Carboniferous.	Des Moines.
		Mississippian, or Lower Carboniferous.	Kinderhook.
	Devonian (?).	Middle Devonian (?).	Cedar Valley (?).

Devonian System.

CEDAR VALLEY STAGE.

All of the indurated rocks which are known to be exposed at the surface in Tama county belong to the Carboniferous system, but all of the exposures which were found over the area occur in the western tier of townships. The successive strata of eastern Iowa outcrop at the surface in a general northwest-southeast direction, and lines which in a general way mark out the known area of the outcrops of the rocks of the Devonian system in the state would include the northeast corner of Tama county. The rock exposures which were found nearest to this portion of the county occur a few miles to the eastward along the tributaries of the Cedar river. At these points the uppermost members of indurated rocks belong to the Cedar Valley stage of the middle Devonian series. From the above consideration there seems little doubt but that the rocks of the same age immediately underlie the superficial materials as far westward as the borders of Tama county.

Of the rocks of the Carboniferous system there are found within the area deposits of both the Pennsylvanian and the Mississippian series. Of the latter series there is represented only the lowest or earliest stage—the Kinderhook. Of the Pennsylvanian series there are found only sandstones which belong to the Des Moines stage.

Lower Carboniferous or Mississippian Series.

KINDERHOOK STAGE.

The name Kinderhook was applied to this assemblage of strata by Meek and Worthen* from the fact that the rocks of this age are well developed and typically exposed near the town of Kinderhook in southern Illinois. In discussing the Kinderhook beds as they are exposed in Tama county Professor Whitney speaks of their close resemblance to the Burlington member of the Carboniferous limestone as that member is developed at the city of Burlington.† Professor Hall referred the beds now included in the Kinderhook stage to the Chemung group of the Devonian.‡ Dr. C. A. White designated the rocks of this stage as the Kinderhook beds,§ and gives a section showing the character of the layers as they are exposed at Burlington through a vertical height of 109 feet.

The rocks of the Kinderhook stage in Iowa extend from Cerro Gordo county in the northwest to the bluffs of the Mississippi river in the county of Des Moines. As these rocks are exposed in Tama county they present three different facies. The lowest phase is a yellow, fine-grained sandstone which bears but few fossils and which is seen in but a few of the outcrops in the area. Overlying this sandstone is a stratum of light colored, oölitic limestone which occurs in thick massive layers. This phase is very fossiliferous throughout and is quite uniformly developed and constantly present wherever in the county the rocks of this horizon are exposed. The upper phase is a brown magnesian limestone which in some layers changes to a yellowish brown, fine-grained sandstone. The layers of this upper phase

*Meek and Worthen: Am. Jour. Sci., Vol. XXXII, p. 228.
†Hall: Geology of Iowa, Vol. I, pt. 1, p. 268.
‡Hall: Geology of Iowa, Vol. I, pt. 1, p 90.
§White: Geology of Iowa, Vol. I, p. 191.

carry quite a number of fossils, usually in the form of casts or moulds. Near the upper part the magnesian character gives way to thinly bedded limestone which in the uppermost layers exposed, carries a large quantity of the comminuted fragments of the stems of crinoids.

The general character of the rocks of the Kinderhook stage as those rocks are developed in this region, together with their order of superposition may be seen from a study of a few typical sections.

Typical Exposures.—Near the east side of section 17 of Indian Village township, in an old quarry just on the south side of the town of Butlerville, there is exposed the following succession of rock layers.

		FEET.	IN.
14.	Yellowish brown loess	2	
13.	Brown clay containing numerous crystalline pebbles	6	
12.	Bed of grayish brown, impure limestone which breaks up into narrow layers and irregular pieces when exposed to the action of the weather. Fossils rare	3	
11.	Band composed largely of nodules of chert		3
10.	Impure limestone, brown in color, with few fossils, species of Chonetes, Rhynchonella and Spirifer were found	1	
9.	Band of chert nodules		3
8.	Thick, heavy layer of brown magnesian limestone containing casts of Chonetes and Rhynchonella	2	6
7.	Layer composed mostly of nodules of chert		4
6.	Layer of brown magnesian limestone with casts of Zaphrentis, Chonetes and Rhynchonella		10
5.	Brown limestone with numerous chert nodules intermingled, containing casts of a species of Productus		10
4.	Massive layer of brown magnesian limestone in which there is a considerable quantity of sand	4	8
3.	Heavy layer of oölite which weathers into small irregular blocks and bits, containing in abundance *Orthothetes crenistria* a species of Rhynchonella, *Spirifer extenuatus*, *Spirifer biplicatus* and *Straparollus latus*	5	8
2.	Massive beds of oölite in two layers similar to number 3 above and carrying similar fossils the lower portion somewhat talus covered	8	6
1.	Yellowish sandstone with some clay containing few fossils, not well exposed, to level of road	8	

A few rods to the west of this exposure, near the house of Mr. Blodgett, there is an outcrop of a few feet of thinly bedded, impure limestone which would occur above the uppermost member

Fig. 24. View of the Butlerville quarry in section 17 of Indian Village township. The heavy ledge exposed at the base is oolite. The layers worked constitute the arenaceo-magnesian bed which immediately overlies the oolite.

of this section, the upper layers of which are crinoidal in character.

The beds above number 3 contain a few fossils but not nearly so many as appear in the layers of oölite. The quarryman, Mr. Dawson, stated that he had found numerous fish remains and crinoids in the seams which part the layers of magnesian limestone. Numbers 4, 6, 8 and 10 of the layers of magnesian limestone are the rocks mostly used for purposes of masonry. The oolite yields rapidly to the weathering action of the atmosphere, crumbling into small irregular pieces. This oölite was formerly burned in large quantities for lime.

All of the beds at this quarry are cut by numerous wide joints into irregular blocks. Some of these joints are filled with a dark

colored, highly carbonaceous shale, which is very probably of Upper Carboniferous age. However, the Coal Measure deposits have all been removed from the upper surface of the rocks in this quarry.

At the present time number 1 in the above section is not well exposed. The layers which overlie the oolite are more desirable stone for general purposes and hence they have been worked back further into the hill than the beds which lie below them. The stripping and talus have been dumped over the edge of number 3 so as in some places to conceal number 1 and the lower portion of number 2 from satisfactory observation.

In his report on the Geology of Iowa, Professor C. A. White gives the following section of this same quarry as it was exposed in 1869.*

		FEET.
3.	Soft, irregularly bedded, magnesian limestone passing up into purer and more regularly bedded limestone	40
2.	Light gray oölitic limestone in heavy layers	15
1.	Yellowish, shaly, fine-grained sandstone	20

In the above section it will be readily seen that number 1 corresponds with number 1 of the section of the Butlerville quarry as it appears today. Number 2 of White's section is the equivalent of numbers 2 and 3 of the present quarry section while number 3 of White's section includes numbers 4 to 12 as they are at present exposed at the Butlerville quarry. At the time Dr. White visited the region the beds below the oolite were better exposed and to a much greater depth; the limestone layers at the top were also to be seen in greater thickness than they are today.

About one and one-fourth miles west of Butlerville, near the southwest corner of section 8, a quarry is opened on land owned by C. J. Stevens of Montour. At this place the outcrop presents the following section:

*White: Geol. of Iowa, Vol. I, p. 196.

		FEET.	IN.
15.	Gray crinoidal limestone which weathers into thin pieces	1	
14.	Crinoidal limestone, gray in color, with numerous fossil fragments		8
13.	Fissile limestone in thin layers, few fossils	4	
12.	Brown magnesian limestone with layer of chert nodules two inches in thickness at the top		9
11.	Bed of rather soft, friable sandstone, much water seamed and containing numerous chert nodules, fossils few	7	
10.	Arenaceo-magnesian limestone, fine-grained and quite hard, brown in color, layers 8 to 12 inches in thickness containing casts of a species of Chonetes, Productus, Rhynchonella and Spirifer	4	
9.	Bed of incoherent, brown, fine-grained sand	1	2
8.	Band made up of chert nodules		4
7.	Impure arenaceo-magnesian limestone, few fossils	1	1
6.	Bed composed largely of nodules of chert carrying a layer of sand, 3 inches in thickness	1	
5.	Magnesian limestone containing some fine-grained yellow sand	1	8
4.	Bed similar to number 5 above	1	6
3.	Layer of massive oölite weathering into small bits and bearing numerous fossils among which appear *Orthothetes crenistra*, *Spirifer biplicatus*, *Spirifer cf extenuatus* and *Straparollus latus*	7	
2.	Layer similar to number 3 above in lithological characters and fossil contents	4	6
1.	Layer of light gray oölite similar to numbers 2 and 3 above	3	

In the above section it will be seen that numbers 1, 2 and 3 are the equivalents of numbers 2 and 3 of the Butlerville exposure. The sandstone at the latter place which underlies the oölite does not appear in the above section. The impure limestone bed which includes layers 4 to 12 of the above section corresponds with layers 4 to 11 inclusive of the section at Butlerville. The upper limestone, which includes layers 13 to 15 above, represents number 12 at the Butlerville quarry and probably also embraces the limestone layers which appear in the hill near Mr. Blodgett's house.

Fig. 25. View in the Stevens' quarry in section 8 of Indian Village township. The light colored massive bed at the base is oolite. The thin layers at the very top are limestone. The sand and impure limestone layers between contain numerous nodules of chert.

In the southwest quarter of section 21 of Indian Village township there is exposed in a ravine a short distance west of the town of Montour the following section:

		FEET.
3.	Reddish brown clay with numerous pebbles........	4
2.	Layer of light gray oölite containing numerous fossils, among them the following are abundant *Orthothetes crenistria*, *Spirifer* cf. *extenuatus*, *S. biplicatus* and *Straparollus latus*.......	6
1.	Layer of oolite similar in every respect to number 2 above....................................	3½

This is an abandoned quarry which was formerly worked by the Oxford Lime Company. The oölite makes as good a quality of lime as can be obtained from pure calcium carbonate. Large quantities of it were used for lime making before the railroads brought the better grade of lime, made from dolomite, within easy reach of the builder.

It is evident that numbers 2 and 1 above correspond with number 3 and the upper part of number 2 respectively of the Butler-

ville quarry, and with numbers 3 and 2 of the Stevens quarry section. At Montour all of the magnesian and sandstone layers which overlie the oölite at the Butlerville and Stevens quarries have been removed by erosion.

In the southern part of Spring Creek township there is exposed along the east bank of a branch of Deer creek a ledge of oölite to a height of ten feet. This outcrop is the most northern rock exposure known to occur within the county, while none were found further south than the one at Montour. The rocks along Deer creek are essentially similar in lithological characters and fossil contents to those exposed at Montour.

Near the southeast corner of section 7 of Indian Village township there is a narrow bluff of rocks extending northward into

Fig. 26. The Devil's Anvil. A tongue shaped lobe of Kinderhook limestone extending into the low river valley in the southern part of section 7, Indian Village township. At the extreme righ appear the bluffs across the river valley.

the flood plain of the Iowa river. This peculiar outlier has a vertical height of about fifty feet above the valley and is known locally as the "Devil's Anvil." There is exposed in the east side of this hill the following succession of layers:

[illegible] is to be seen [illegible] of the oolite [illegible] given. The layers of [illegible] numbers 2 to 6 [illegible] character giving [illegible] layers vary- [illegible] that are but a short distance apart. [illegible] correlated with [illegible] quarry and with [illegible] of the Stevens quarry section. The [illegible] these arenaceo- [illegible] beds and which constitute the uppermost numbers of [illegible] of the Kinderhook stage in the county is also variable [illegible] not widely separated, a larger amount having been

removed by erosion at some points than at others. However, the corresponding beds as a whole can be readily recognized at all of the exposures where these uppermost beds are present.

About three-fourths of a mile north of Butlerville in the south bank of the river there is an abandoned quarry which was formerly worked by Messrs. Stevens and Gray. At this place there is exposed about six feet of oölite at the base, which is succeeded by twenty-three feet of irregular layers of brown arenaceo-magnesian limestone interlaid with bands and numerous chert nodules. The indurated rocks are overlain by about six inches of oxidized bowlder clay and that in turn is covered with about one foot of loess soil. Outcrops such as the last might be multiplied along the bluffs of Sugar creek. In the last few miles of its course the ledges of rock are exposed at almost every bend of the stream but there are no layers present which do not appear in the Butlerville, Stevens or Anvil exposures, nor were any species of fossils found there which were not seen at the points above mentioned.

The Butlerville section and the succession of beds which appear at the Stevens quarry and the Anvil may be taken as representative of the development of the Kinderhook rocks in Tama county. As will be seen the bed of white oölite is a conspicuous feature in each of these exposures.

In all cases the oölite of Tama county is mixed with a shell limestone, but the predominance of the oölite phase makes that the most conspicuous feature of these layers. Oölite is composed of small, more or less spherical, grains of calcareous matter cemented into a hard mass by the deposition of calcium carbonate. When a fragment of this rock is ground and polished, each little grain is seen to be composed of a number of thin concentric plates surrounding a common nucleus. Oölite was probably formed along an old sea margin which was submerged only during the periods of high tide; in places where, for some reason, the land stood almost at base level so that the streams which drained the surface carried to the sea little or no mechanical sediments; in a region where the climate was suitable for the rapid and abundant growth of brachiopods and other animals which secrete skeletons of lime; in localities, too, where conditions

Fig. 27. Exposure in an old quarry near the southeast corner of section 8, Indian Village township. The floor of the quarry is of oolite, a little of which is shown at the base of the quarry. The middle portion shows bands of chert intercalated between the irregular layers of impure limestone. Thin layers of crinoidal limestone appear at the top.

were favorable for some concentration of calcium carbonate in the sea water. As the waves swept far up over such low beaches they would grind into tiny bits the fragments of shells which they rolled back and forth along the bottom and so cover the shore with minute grains of calcareous sand. Every time the tide rose and again receded a film of sea water would be left surrounding these tiny spheres which upon evaporation would deposit a pellicle of lime around the grain. In this manner the little spherules slowly grew by addition constantly on the outer surface. and finally the adjacent grains and fragments of shells were all firmly cemented together by an interstitial deposit of this same substance from the waters of that ancient sea.

It is by some such process as this that oölite is forming at the present time along the shores of tropical seas, and geologists believe that nature has worked in the past by the same methods as are used at present to secure like results.

The fossils which were found in the layers of oölite represent no great variety of forms but the individuals of the most of the species were very abundant. The following were collected from this bed:

Orthothetes crenistria Phillips.
Chonetes logani ? Hall.
Productus cf. *arcuatus* ? Hall.
Productus sp.
Orthis swallovi Hall.
Rhynchonella sp.
Spirifer cf. *marionensis* Shum.
Spirifer biplicatus Hall.
Spirifer sp.
Syringothyris extenuatus ? Hall.
Athyris sp.
Straparollus latus Hall.
Dexiobia ovata Hall

The layers of yellowish sandstone which underlie the oölite were seen at no point further west than the Butlerville quarry. At this place the beds were not very well exposed and no trace of fossils was found.

The arenaceo-magnesian beds which overlie the oölite were probably also deposited at no great distance from the shore along a zone that was subjected to variable conditions. They were formed during a period when the process of erosion was quickened and the streams brought down from the uplands greater quantities of sediment. The following animals peopled the waters during the time these rocks were being laid down.

Fenestella sp.
Zaphrentis sp.
Orthothetes crenistria Phillips
Chonetes sp.
Productus sp.
Rhynchonella sp.
Spirifer sp.

The limestone layers at the top of these sections record a gradual subsidence resulting in the diminution of erosion, allowing the building up of limestone layers from the shells or skeletal parts of the successive generations of sea animals, among which the crinoids were preeminent. The materials of these layers are so finely comminuted that but few of the fossil fragments

which they contain could be recognized. Among them were the following:

Chonetes sp.
Rhynchonella sp.
Spirifer sp.

Some time ago a collection of fossils from the above beds was sent to Professor Stuart Weller of the University of Chicago for identification, but up to the present date he has not had time to examine and report concerning them; hence the meagreness of the list of species found above.

In the discussion of the rocks of the Kinderhook stage in Marshall county, Dr. S. W. Beyer makes the following subdivisions.*

		FEET.
4.	Brown and gray subcrystalline limestone	30
3.	Buff magnesian limestone, cherty below	35
2.	Gray-white oolite	15
1.	Argillaceous blue sandstone	20

Above number 4 he places provisionally about fifteen feet of argillo-calcareous beds which are exposed at Marshalltown, but which bear no fossils. In the Marshall county section number 1 is the equivalent of number 1 of the Butlerville section. Mr. Beyer speaks of observing casts of fossils in this bed but mentions none of the forms which they contain. Number 2 above corresponds with numbers 2 and 3 of the Butlerville quarry. Mr. Beyer speaks of this bed being fossiliferous throughout, among which forms he found:

Entolium circulus Shum.
Straparollus latus Hall.
Productus sp. and fish spines and plates.

In the third number above he found:

Chonetes sp.
Praductus arcuatus Hall.
Orthothetes crenistria Phillips.
Rhynchonella sp?
Spirifer biplicatus Hall.
Spirifer sp,
Spines of fishes.

This number is identical with numbers 4 to 12 inclusive of the quarry section at Butlerville. It is probable that number 4 of

*Iowa Geol. Surv., Vol. VII, p. 222, *et seq.*

Beyer's section is represented in Tama county by the limestone layers which overlie the arenaceo-magnesian beds at the Butlerville and Stevens quarries and in the Anvil exposure. It is not developed to such a thickness in Tama county as it is farther west. The shales which are found at Marshalltown have no counterpart within the area under consideration.

In his report on the Geology of Iowa Dr. White gives the succession of the Kinderhook beds as they are exposed at the city of Burlington.* The condensed reproduction of his Burlington section is given below.

		FEET.
7.	Impure limestone, sometimes magnesian, passing gradually into the Lower Burlington, disintegrating more readily than the overlying Burlington limestone	3-4
6.	Light gray oolitic limestone, very uniform in lithological characters	2-4
5.	Fine-grained yellowish sandstone, often crowded with casts of fossil shells, embracing many genera and species some of which are peculiar to this bed alone. The fossils of this bed are usually small Lamellibranchs and Brachiopods	7
4.	Dark gray compact limestone, sometimes slightly arenaceous, breaking up into small fragments on exposure and is very fragmentary even when not exposed to the atmosphere	12
3.	Oölitic limestone, interesting as showing the tendency of the limestones of this formation to assume this structure	¼
2.	Layer of compact limestone everywhere crowded with shells, principally Chonetes	½
1.	Composed largely of fine-grained sandy shales, but varying from bluish clayey shales to fine-grained yellowish sandstone, greatest thickness exposed	82

No. 1 is recognized in well borings at a depth of 65 feet below the above measurement, making the entire recognized thickness of this member 147 feet.

Mr. White considered number 1 of his Burlington section to be the equivalent of number 1 of his section of the Butlerville exposure; number 6 at Burlington to be the representative of number 2 at Butlerville, and number 7 at Burlington to be the counterpart of number 3 at Butlerville.† He seemed to think that

* White: Geol. of Iowa, pp. 192 and 193.
† Ibid: p. 196.

numbers 3 to 5 inclusive of the Burlington section were not represented at Butlerville at all. Dr. White speaks of the upper portion of number 1 at Burlington being quite fossiliferous in some places and states that the characteristic fossils of the Kinderhook formation prevail throughout the whole series of beds found at Indiantown (Butlerville) but he does not mention any of the species that were found at either exposure. In the spring of 1899 Professor Stuart Weller made a study of the rocks of the Kinderhook stage as they are exposed at Burlington. Mr. Weller makes the following section of these rocks which differs from White's only in dividing number 1 and combining numbers 2 and 3.*

		FEET.
7.	Soft, buff, gritty limestone	3-5
6.	White oölitic limestone	2-4
5.	Fine-grained yellow sandstone	6-7
4.	Fine-grained, compact, fragmental, gray limestone.	12-18
3.	Thin band of hard impure limestone filled with Chonetes; sometimes associated with a thin oolite band	¼-¾
2.	Soft, friable, argillaceous sandstone sometimes harder and bluish in color, filled with fossils in the upper portion, the most abundant of which is *Chonopectus fischeri*	25
1.	Soft, blue, argillaceous shale (exposed)	60

As will be seen numbers 4 to 7 inclusive of Weller's section are identical with the corresponding numbers in the section of Dr. White. In number 6 of the above section, which White considers the equivalent of the oölite layers in Tama county, Weller mentions the following list of fossils which have been observed †

Zaphrentis sp. undet.
Leptæna rhomboidalis Wilck.
Orthothetes inflatus W. and W.
Chonetes logani N. and P.
Chonetes illinoisensis Worthen.
Productus arcuatus Hall.
Productella concentricus Hall.
Schizophoria subelliptica W. and W.
Rhipidomella sp. undet.
Dielasma allei Win.

* Weller: Iowa Geol. Surv., Vol. IX, p. 65.
† Ibid: p. 78.

Spirifer marionensis Shu.
Athyris crassicardinalis White.
Pernopecten circulus Hall.
Conocardium pulchellum W. and W.
Straparollus obtusus Hall.
Pleurotomaria quinquesulcata Win.
Loxonema sp. undet.
Capulus sp. undet.
Orthoceras indianensis Hall.
Gyroceras burlingtonensis Owen.

From bed number 7 of Weller's section, which White considered the representative of the arenaceo-magnesian layers which overlie the oölite in Tama county, Mr. Weller names the following species:

Leptopora typa Win.
Orthothetes inequalis Hall. (?)
Orthothetes inflatus W. and W.
Productus punctatus Martin.
Camarophoria caput-testudinis White.
Rhynchonella persinuata Win.
Spiriferina solidirostris White.
Nucleospira barrisi White.
Bellerophon panneus White.
Pleurotomaria mississippiensis W. and W.
Igoceras undata Win.
Capulus paralinus W. and W.
Capulus vomerium Win.

From a comparison of the fossils which appear in number 6 of the Burlington section with those which occur in the oölite beds of Tama and Marshall counties, which members Dr. White thought were equivalent, it will be seen that there is a very marked difference between the fauna of the respective members. It is possible, however, that when Mr. Weller completes the study of the fossils of the Kinderhook stage in central Iowa that these differences may become less conspicuous, and the resemblances may grow more apparent. In like manner the assemblage of fossils which is found in the arenaceo-magnesian beds overlying the oölite in Tama and Marshall counties is quite different from that found in number 7 of the section at Burlington, with which member Dr. White considered the arenaceo-magnesian beds to correspond.

If the rocks of the Kinderhook stage which are found in Tama and Marshall counties were deposited contemporaneously with any of those of the corresponding stage at Burlington, it is possible that Dr. White was correct in his correlations as given above. Lithologically the oolite beds of this horizon in central Iowa resemble very closely number 6 of the Burlington section. A larger proportion of the fossils which are found in the oölite layers is similar to those found in number 6 than to those of any other member of the Burlington section. Also the beds immediately overlying the oölite in Tama and Marshall counties are as nearly similar in lithological characters and fossil contents to number 7 as to any other member of the section at Burlington. It will be evident, however, that if this is the true interpretation of the relation of the Kinderhook rocks which occur in the counties of Tama and Marshall to those exposed in the bluffs along the Mississippi river at Burlington, there must have been very peculiar conditions attending the deposition of these materials to result in the wide differences in the animals which peopled the waters along that ancient shore at the two points separated by such a short distance. What those conditions could have been is not at present understood.

The limestone beds of the Kinderhook stage which overlie the arenaceo-magnesian layers in central Iowa seem to have no probable equivalent further south. The sandstone member which underlies the oölite in Tama and Marshall counties is not sufficiently well exposed over this area to permit even an approximate determination of its equivalent in the exposure of the rocks of this state at the city of Burlington.

Upper Carboniferous or Pennsylvanian Series.

DES MOINES STAGE.

The deposits of the Lower Carboniferous series were closed by a crustal movement that raised this portion of the state above the sea. For an exceedingly long period, measured by three geological ages, the area which embraces Tama county was a land surface, exposed to all the denuding effects of weathering and erosion to which such areas are subjected at the present time. Deep gorges and wide valleys were carved in the level strata of

the Kinderhook stage and doubtless a great depth of rock materials which were once laid down above the highest layers that at present are found in the area was swept entirely from the surface and carried down to the sea, contributing to the sum of the sediments which make up the rocks of the Augusta and the Saint Louis stages farther to the south and west.

Finally the oscillations of the crust resulted in the submergence once more of the greater portion of Iowa. The area under discussion was involved in this catastrophe, and deposits of sediments once more accumulated over the region, filling all of the old valleys and burying deeply the gashed and furrowed surface beneath a covering of sand and shale and seams of coal which constitute the deposits of the Des Moines stage of the Pennsylvanian series.

This portion of the state did not remain beneath the waters so long as areas lying further to the south and west. With an upward movement of the crust the region was again added to the domain of the land. This new land was immediately attacked by the quiet agents of the atmosphere and the more rapid action of the rains and streams. During the rest of the Paleozoic era, the whole of the Mesozoic and the greater portion of the Cenozoic it was being carved and worn and wasted; reduced to base level, only to begin a new cycle of erosion with each new elevation of the land. The whole of the deposits of the Des Moines stage was eroded from the surface except a few small patches occupying old channels in the Kinderhook rocks, which were not again appropriated by later streams. Protected in these depressions from the general denudation that removed the great mass of the sediments of the Des Moines stage, these isolated remnants witness to the profound changes which this region has undergone.

Near the central part of section 9 of Indian Village township there is exposed in a ravine on the north side of the wagon road a bed of sandstone about six feet in depth which was thought to be of Des Moines age. The sand here is quite incoherent when long exposed to the weather, except where the grains have been cemented together with an interstitial deposit of iron. It is yellowish brown in color and coarser grained in texture than any that had been found in the deposits of the Kinderhook stage in that region.

No remains either of plants or animals were found in these layers. This bed was in a valley thirty feet lower than the tops of the ledges which form the bluffs of the Iowa river scarcely one-half mile away. The pockets and joints filled with carbonaceous shale which are found at the Butlerville quarry would also indicate that the entire surface of the county had been covered with these Upper Carboniferous deposits, the most of which had subsequently been removed by erosion before the beginning of the Pleistocene period.

Pleistocene System.

During the excedingly long interval that elapsed between the elevation which closed the deposits of the Upper Carboniferous series over this area and the initiation of the Pleistocene period not only had the surface suffered great denudation and deep erosion but the rock materials had slowly disintegrated in excess of what was removed by the streams and thus a soil was formed which, as it gradually grew deeper, protected the underlying rocks from the most rapid decay. Slowly as the soil accumulated plants appeared, and at length the surface became clothed with vegetation and peopled with abundant forms of animal life. It was after the long continuance of such a condition of things as this that the Pleistocene period was introduced. During the early part of this period ice sheets were pushed down from the north over this area, bringing with them great quantities of clay and bowlders and rock debris. These materials were spread out over the surface of the county to such a depth that the streams have succeeded in cutting their channels through the covering of drift in but few places so as to reveal the indurated rocks which underlie it. The Glacial series is represented in Tama county by three different sheets of drift, deposits of loess and beds of alluvium.

PRE-KANSAN DRIFT.

Near the southwest corner of section 19 of Toledo township a cut has been made in a hill in order to make wider the road bed of the Chicago and Northwestern railroad. At this place the following section has been exposed.*

*Savage: Drift Exposure in Tama county, Proc. Iowa Acad. of Sciences, Vol. VIII, p. 275.

		FEET.
5.	Fine-grained, yellow colored clay without gravel or bowlders	4½
4.	Bed of sand in alternating bands of finer and coarser grained material	8
3.	Bed of bluish colored clay containing numerous pebbles and bowlders many of which are decayed	24
2.	Band of brown colored, somewhat sandy soil containing impressions of vegetable remains and pieces of wood	1½
1.	Bed of blue clay with numerous pebbles and bowlders down to the base of the exposure, pre-Kansan	16

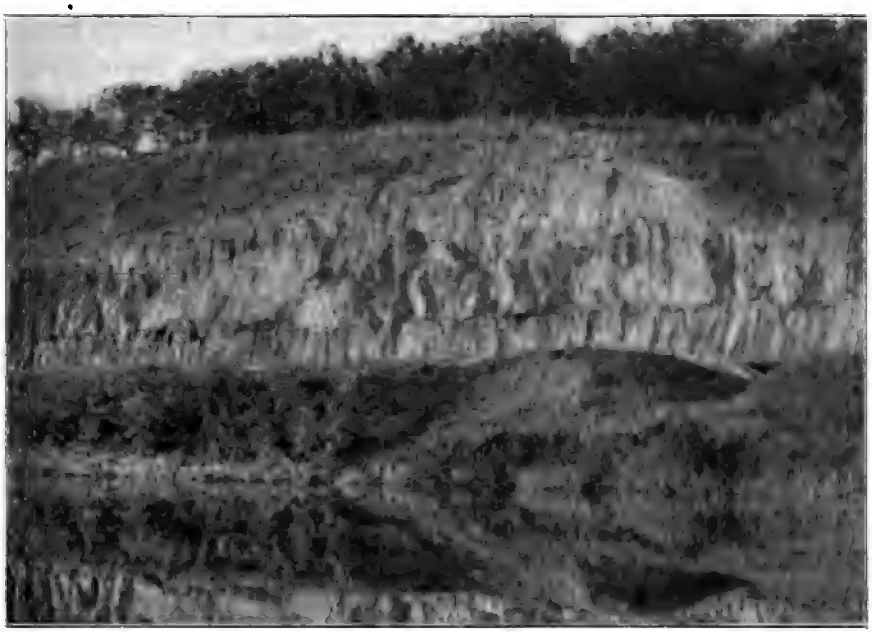

Fig. 28. Exposure in a cut along the Chicago & Northwestern Railroad near the southwestern corner of section 19, Toledo township. The drift at the base is pre-Kansan, that at the top is of Kansan age, the horizontal band a little below the middle of the section represents an old Aftonian soil horizon. (Photo by Mr. J. M. R. Hanson.)

In the above section number 5 is the common fine-grained, yellow loess that forms the surface soil over the most of the neighboring uplands. Number 4 is a bed of loose sand in which the layers of finer-grained material alternating with those of coarser texture indicate a deposit along the channel of a stream in which the strength of the current was variable. The layer of sand was probably deposited along the bed of a stream that

carried off the waters which resulted from the melting of the Kansan ice. Number 3 is a thick bed of bowlder clay, containing numerous pebbles and bowlders of various sizes, many of which show marks of glaciation. Quite a large proportion of these pebbles and small bowlders are dark colored greenstones. Many of the light colored bowlders have so far decayed that they soon crumble to pieces when exposed to the air. This bed of clay represents the Kansan drift. It is of a yellowish color at the top, gradually changing to a bluish color lower down. It is calcareous even at the top which is unusual for the surface of the Kansan drift sheet. It is probable, however, that the bed of sand which overlies this drift has so protected it from the atmosphere as to prevent the leaching of the lime from the clay for some few feet below the surface, as has generally taken place at the upper part of this drift. The bed is cut by numerous joints and cracks into prismatic and irregularly shaped blocks and fragments. Number 2 is a narrow band of dark brown materials composed of more or less perfectly decayed vegetable matter mixed with a soil which contains a considerable amount of sand. This band contains no trace of calcareous matter.. Fragments of wood, bits of roots and dark colored patches of carbonaceous material occur near the upper part of the bed. It forms a conspicuous layer eighteen to twenty-four inches in thickness, which is exposed at this horizon for a distance of several rods. Number 1 is a bed of bowlder clay which resembles number 3 above in color and contents. It does not present such numerous joints as appear in number 3. At the top of the member the oxidation of the iron in the clay has given to the till a slightly yellowish appearance but this change is not nearly so marked as is often seen at the surface of the Kansan drift. The calcareous matter has been almost entirely removed to a depth of one to three feet. A few feet below the soil band prompt and vigorous action when treated with hydrochloric acid reveals the presence of abundance of lime down to the base of the exposure. This lower bed of till is considered of pre-Kansan age. The narrow band containing plant remains and soil constituents represents the old surface of the Aftonian interglacial period, during which interval the leaching at the top of the lower bed of till was slowly accomplished.

In well borings at different points over the county the same bed of bowlder clay is encountered underlying the Kansan drift; but this is the only place within the area where it is known to be exposed at the surface.

A well put down in the spring of 1902 by Mr. William La Due of Toledo, for the Toledo and Tama Electric Car Company, about the middle of the south side of section 20, Toledo township, passed through the following succession of beds as furnished by the well driller:

		FEET.
7.	Fine-grained soil	5
6.	Yellow clay without pebbles	25
5.	Stratum of sand	8
4.	Bed of blue clay containing gravel and bowlders.	42
3.	Bed of sand	12
2.	Bed of blue clay like number 4	40
1.	Very hard lime rock	38

It is probable that numbers 6 and 7 of the above section represent a deposit of loess, the upper part of which has been changed to a darker color by the carbonaceous matter that has been left from the decay of successive generations of vegetable forms which grew upon the surface. Number 5 is a sand bed that was probably laid down along the channel of a stream which carried water while the Kansan ice was melting, but which was abandoned when the ice withdrew from the area and the stream found a lower level for its bed. Number 4 is evidently a bed of Kansan till with its natural color and contents. Number 3 represents a stream deposit of sand that was laid down either during the time of melting of the pre-Kansan ice or in the interval of the Aftonian interglacial period. Number 2 is a bed of pre-Kansan drift which presents the characteristic blue color of this lowest sheet of till as it appears at other points over the state. No fossils were preserved from number 1 of the above section so it is impossible to determine fully the age of the limestone encountered immediately below the drift at this point. From the proximity to the exposures of the rocks of Kinderhook age it would seem probable that these rocks might belong to the basal portion of that stage. However, the lower members of the Kinderhook rocks as they are exposed in Iowa are sandstones or

shales rather than limestone and it may be that the strata encountered in the well boring belong to the Devonian series.

A well drilled on land owned by T. B. Kepler passes through a succession of materials similar to the above but the beds of drift are not so thick. A well drilled on land owned by W. B. Mitchell in Otter Creek township penetrated the following succession of beds:

		FEET.
4.	Dark colored soil	4
3.	Yellow clay with bowlders	95
2.	Blue clay with bowlders	260
1.	Bed of sand so full of water that it lifted drilling tools weighing 500 pounds up 20 or 30 feet, down to hard rock	12

This farm lies within the limits of the Kansan drift plain. In the above record number 4 is a deposit of loess. Numbers 2 and 3 doubtless represent Kansan drift. This drift is usually a bluish gray color in deep beds and it is very remarkable that oxidation should have taken place to such an extent as to give the deposit a yellow color to the depth of ninety-five feet. In number 1 there occurred numerous pieces of wood two to three feet in length and one inch in diameter. The sand also contained numerous fragments of shells. The bed was doubtless occupied by the waters of a stream which drained a portion of this region during the Aftonian interglacial period. The source of the materials may have been the drift of pre-Kansan age or possibly the sand may have resulted from the decay of native sandstone rocks. As will be seen the indurated rocks at this place are buried beneath a deposit of superficial materials 370 feet in depth. This is the greatest depth which these materials are known to have attained within the county.

Mr. Mosnat* has shown that in putting down a well, which he designated as number 98, at Belle Plaine, only about one and one-half miles from the southeast corner of Tama county, the drill passed through layers which are essentially as follows:

		FEET.
4.	Fine-grained loess	15
3.	Bluish colored bowlder clay of Kansan age	210
2.	Gravel and sand of Aftonian age	5
1.	Bed of blue till representing the pre-Kansan drift	18

*Mosnat: Iowa Geol. Surv., Vol. IX, p. 537.

Number 2 is the water-bearing reservoir which is the source of the water in the flowing wells of the Belle Plaine area. There are a number of such wells in the southeast corner of Tama county and there seems no reasonable doubt that the above section represents the general arrangement of the superficial materials over all of the area in which strong flowing wells occur. If this interpretation be correct there is evidence of a sand and gravel bed of Aftonian age underlain by a bed of pre-Kansan till over quite an area in the southeastern portion of this county.

It seems probable that the pre-Kansan drift was a thin sheet which carried an abundance of gravel and that erosion removed a large part of its materials from the uplands before the incursion of the Kansan ice. At least, we have at some points indubitable evidence of an old drift underlying the Kansan and separated from it by a bed of water laid materials or an old soil horizon, the line of contact between the two beds being exposed in the railroad cut described above, while the records of a large number of wells show just as clearly the Kansan drift immediately overlying the indurated rocks over the greater portion of the county.

KANSAN DRIFT.

The area over which the Kansan drift forms the surface till of the county has been outlined under the discussion of topography. The materials of which this drift is composed are very old. The bowlders which it contains are usually much smaller than those carried by the Iowan ice. A larger proportion of them are microcrystalline, dark-colored basic rocks known as greenstones. Many of them have been carried along beneath the ice during a portion of their long journey and present one or more surfaces that have been beautifully planed and striated. A large proportion of the light-colored granites are so thoroughly decayed that they crumble at once into small bits when the surrounding clay is removed.

As the Kansan ice sheet with its crushing weight of materials was pushed down over the old Aftonian surface it gathered up and carried along with it the most of the pre-Kansan drift that still remained on the uplands. It also bore onward the geest and

residuum of the partial decay of the native limestone rocks which had been accomplished since the retreat of the first ice sheet, grinding down into the solid ledges and leaving below it a hard surface which was planed and striated by the rocks of the ground moraine as the mass of ice slowly moved along. Such a glaciated surface exposed for several square feet and overlain by Kansan drift was seen in a quarry in the north bank of the river near the Tama and Marshall county line. These calcareous materials which were gathered up from the rock surfaces became so thoroughly mixed through the Kansan till that the entire deposit was permeated with carbonate of lime. The surface of this sheet has been so long subjected to the leaching action of the rains and to the effects produced by the growth and decay of countless generations of plants, that the lime has been entirely removed to a depth of two to five feet. The iron also which the drift contained has been so long exposed to the oxidizing action of the atmosphere that to a depth of three or four feet the clay presents a dark reddish-brown color, instead of its typical bluish-gray, on account of the ferric oxide which it contains. For several feet below this red colored zone the clay is usually a yellowish-brown, grading down into the unchanged drift sometimes at a depth of fifteen to twenty feet. Examples of such surfaces of red colored clay which is thoroughly leached of calcareous matter are exposed in the ravines along the roadside between sections 29 and 30 of Richland township and again along the south side of section 17 of Toledo township, and at numerous other points over the county. In fact, this is the usual condition of things wherever the Kansan drift is exposed for a few feet below the surface.

So exceedingly old is this sheet of till that its surface was practically carved as deeply and dissected as thoroughly as it is today before the advent of the Iowan ice. This is evidenced by the fact that the hills immediately adjacent to the border of the Iowan drift plain, which received deposits of loess and sand during the time the Iowan ice prevailed, present a leached and oxidized zone at the line of contact between the drift of the hill and the loess or sand which forms its crown. This oxidized zone is continued well down the flanks of the slopes. The loess and sand were laid down over a surface which had essentially the present

erosional features before their deposition, those beds only increasing a little the difference in altitude between the valleys and the tops of the hills. Over the more deeply loess-covered regions of the county—and all of the Kansan area is loess covered—the ravines along the roadsides in multiplied instances reveal the old oxidized surface of the Kansan conforming with the present contour of the hills; the top of the loess mantle lying parallel with and duplicating almost every inequality in the surface of the underlying drift.

The following well records from various points in the county reveal the till of Kansan age immediately overlying the indurated rocks.

In section 1 of Toledo township a well on land owned by J. W. Schoolcraft penetrated the layers indicated below:

		FEET.
3.	Dark colored, fine-grained soil (loess)	3
2.	Yellow clay (loess)	35
1.	Blue clay (Kansan) with bowlders down to sandstone	140

In section 7 of Otter Creek township a well on the farm of Mr. Elmer Dowd gave the following succession of beds:

		FEET.
4.	Yellow clay, fine-grained (loess)	40
3.	Blue clay with bowlders (Kansan)	175
2.	Shale rock (Kinderhook)	25
1.	Hard limestone	78

In section 17 of Toledo township a well drilled on the farm of J. A. Berger shows the following:

		FEET.
7.	Soil, fine-grained (loess)	4
6.	Yellow clay with gravel and small stones (Kansan).	40
5.	Blue clay with bowlders (Kansan)	176
4.	Shale	5
3.	Limestone	20
2.	Shale	160
1.	Hard, blue limestone	15

In the town of Chelsea, Salt Creek township, a well on land owned by J. W. Shaler gives the following record:

		FEET.
5.	Dark colored soil (alluvium)	4
4.	River deposit of clay, sand and gravel (Recent)	33
3.	Blue clay with bowlders (Kansan)	148
2.	Shale (Kinderhook)	30
1.	Limestone, hard (Devonian)	18

A well in section 29 of Salt Creek township on the farm of J. P. Wilkson penetrated the following beds:

		FEET.
5.	Dark colored soil (alluvium)	4
4.	Clay, sand and gravel (Recent)	30
3.	Blue clay with bowlders (Kansan)	174
2.	Shale (Kinderhook)	80
1.	Limestone (Devonian)	84

In section 36, Otter Creek township, a well section on land owned by N. Blazek is as follows:

		FEET.
5.	Soil (alluvium)	5
4.	Water-laid materials (Recen)	30
3.	Blue clay (Kansan)	165
2.	Shale (Kinderhook)	100
1.	Hard limestone (Devonian)	20

Mr. McGee gives the following record of a well drilled in section 13 of Clark township for the Chicago & Northwestern Railway:

		FEET.
4.	Yellow clay containing pebbles (Iowan)	12
3.	Sand (Inter-Kansan-Iowan)	19
2.	Blue clay with bowlders Kansan)	150
1.	Sand (Aftonian)	15

The first three of the above records were furnished by the well driller, Mr. W. H. La Due of Toledo. The three following were taken from Mr. R. Mosnat's report on the artesian wells of the Belle Plaine area* and the last one was taken from W J McGee's Pleistocene History of Northeastern Iowa.†

Gravels.—There are no gravels of Buchanan age known to occur in Tama county, but on the hill slopes in a few places there are thin sheets of pebbles and small bowlders overlying the Kansan till which simulate deposits of the Buchanan gravels. Professor Calvin found at different points in Page county a layer of gravel conforming to the line of contact between the Kansan till and the overlying loess.‡ He has shown that the gravel in these sheets was originally distributed through that part of the Kansan drift which has subsequently been removed by erosion. The finer clay portion of the till was easily carried away by the waters

*Mosnat: Iowa Geol. Surv., Vol. IX, p. 556.

†McGee: Eleventh Ann. Rep. U. S. Geol. Surv., p. 529.

‡Calvin: Iowa Geol. Surv., Vol. XI. pp. 442 and 443.

which drained the general surface while the pebbles from quite a thickness of the drift, being too heavy to be carried along by the surface water, became concentrated in a thin bed by the removal of the finer materials. It is by some similar process that the thin gravel bed which overlies the Kansan drift along the roadside between sections 13 and 14 of Highland township and again between sections 19 and 30 of Howard township was formed.

IOWAN DRIFT.

The Iowan drift sheet extends over three-fourths of the surface of Tama county. The areas which it covers have been already described. As a general rule the Iowan ice which moved over the portion south of the river and over the Toledo lobe was so thin and the amount of materials which it carried was so small that in many places the erosional features of the Kansan till were not greatly modified. To discriminate between such Iowan areas and those of the less eroded Kansan surface is not always an easy task. Usually, however, the Iowan ice left large bowlders of gray granite at more or less frequent intervals on the surface over which it passed. Wherever these appear in the fields and along the courses of the streams there are topographic features accompanying them which together constitute quite distinctive criteria. So constant is the presence of occasional bowlders over the Iowan area, even where it left but slight traces in the topography, that its outlines could almost be mapped from the presence of these fresh granite bowlders in the foundations of corn cribs and other buildings on the farms over the Iowan plain. Usually only the smaller ones have been removed from the cultivated fields.

Adjacent to the larger streams the Iowan surface is well dissected and thoroughly drained. The tributaries, however, are usually short and they always rise in broad, ill-drained marshy sloughs with undefined channels which are utterly unlike the sharply angular trenches and furrows that form the source of the streams of the unmodified Kansan drift plain. The hills of these hybrid regions are slightly lower and present more rounded outlines than those in the Kansan area. They lack the sharp, bold contours and abrupt slopes so characteristic of the older drift surface.

Fig. 29. Typical marsh in the Iowan drift plain. In such swamps the streams of the area take their rise.

Over large areas the finer materials of the Iowan drift have been entirely removed. The undisturbed, red-colored Kansan till, thoroughly oxidized and deeply leached, that appears at the tops of the hills and continues well down the slopes, testifies to the very small amount of ice that has moved over them. Where the Iowan drift is exposed it is of the usual yellowish color, not more oxidized at the top than at the base of the deposit, and unleached at the very surface of any of its calcareous constituents. Small beds of this drift are frequently seen at the foot of the hills over the hybrid areas, but care needs always to be exercised in its discrimination, for in color and calcareous contents this material resembles the portion of the Kansan drift lying between the thoroughly oxidized ferretto zone at the top and the unchanged blue clay of the deeper portions of the bed. Erosion has frequently exposed this yellow calcareous Kansan till near the base of the hills. This older drift, however, carries a larger number of pebbles and small bowlders, a large proportion of which are fine-grained and dark in color. The bowlders of granite are frequently much softened and decayed. At several places over the hybrid areas the yellow Iowan till is seen overlapping the ferretto zone of the Kansan, as along the north side of section 35 of Howard township, be-

tween sections 23 and 26 of Crystal and between sections 13 and 14 of the township of Highland. Over most of the northern portion of the county the Iowan till presents a level unsculptured surface which is typical of this recent drift plain. Its youthfulness is depicted in every feature of this deposit. The agents of erosion have scarcely yet begun their work. The constituents of the till are unchanged at the very top. The granite bowlders are almost as fresh and sound as when they left their native ledges. Every criterion of age attests the recent deposition of the Iowan materials. In comparing the age of the Iowan drift with that of the Kansan, Professor Calvin says,* "If it should be claimed that the Kansan is a hundred times as old as the Iowan, I know of no facts at present that would disprove the claim. If some one should estimate the age of the Kansan as

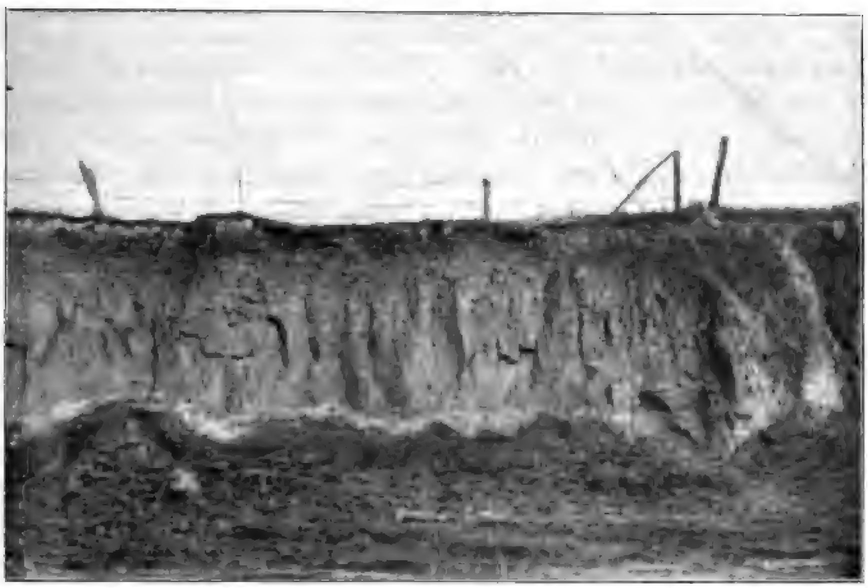

Fig. 80. Exposure of fossiliferous loess in the clay pit of Mr. Bentley, about 18 feet in depth. The view shows the tendancy of this material to stand in vertical walls in excavations. A slightly lamina ed structure is present near the top.

fifty times as great as that of the Iowan, I should be compelled to acknowledge that the estimate is very conservative." All of the facts that are presented in Tama county relative to the age

*Calvin: American Geologist, December, 1902, p. 38.

of the Iowan and the Kansan till would support the former of the comparisons given above.

Loess.—The general relation of the loess to the Iowan and the Kansan drift sheets in Tama county is consistent with its distribution over the greater portion of Central Iowa near the margin of the Iowan drift plain. Loess forms a mantle at the surface over all of the Kansan area and covers with a thin sheet the most of the southern portions of the Iowan drift. Immediately adjacent to the Iowan border the deposits are deep. The materials here are largely composed of sand although the occurrence of beds of the finer loess clay is not infrequent. Over all of the other loess covered areas the deposit is a very fine-grained, yellow colored silt containing no sand or pebbles and covering alike the summits, slopes and valleys. At numerous points the beds of loess attain a depth of fifteen to twenty-five feet. In many of these deeper deposits the shells of air-breathing univalves are abundant throughout the entire depth. In such beds the loess is usually quite calcareous. The segregation of the lime in the form of small nodules or concretions, loess-kindchen, along a line six to eight feet below the surface, occurs in a loess exposure near Tama in the southern part of section 25 of Tama township. These concretions are usually irregular in shape, two or three inches long and about one inch in diameter of cross section. They are generally impure, containing much clay material.

Even the deeper deposits of loess seldom present anything resembling lines of stratification, and when lamination planes are present they are such as might readily be formed in the deposit of wind blown materials.

All of the features connected with the deposit of loess in Tama county are such as might be developed through the agency of the wind. The presence of the fragile yet unbroken shells of land mollusks distributed through the entire thickness of the beds would indicate that each portion of the deposit had successively been a surface and that the shells were slowly buried by the accumulation of the materials after the animals that inhabited them had died. The fact that the loess mantle does not tend to level up the surface but duplicates the inequalities of the underlying drift would strongly suggest that it was laid down by the wind.

The absence of usual stratification planes would be at variance with what would be expected to result from the sorting action of water if the materials were laid down by that agency.

Deposits of fine-grained, loess-like beds are forming at the present time wherever dust-laden winds have their velocity checked and especially where a carpet of grass or other vegetation covers the surface in such places so as to retain the dust that falls upon it.

Even the deeper beds adjacent to the Iowan border may possibly have been deposited by the same agent. Professor Calvin has shown that the materials of the loess of central and southern Iowa were probably derived from the finer constituents of the Iowan drift. The evidences which point to this source of the loess are its color and composition, its geographical relation to the Iowan border, and its superposition sometimes on the oxidized surface of the Kansan till and sometimes on the Iowan.* It would seem that the conditions during the time the Iowan ice prevailed would be exceptionally favorable for strong northerly and westerly winds whose sweep over the surface of the ice sheet would be unobstructed by great inequalities of surface or by the presence of forest areas. Then, too, the finer loose materials that were liberated as the general surface of the ice wasted by melting would be in prime condition to be gathered up and swept along by the winds. Much of these materials would probably be laid down around the margin of the ice, but some of the finer portions might readily be carried far beyond the border of the ice sheet. It would seem probable, too, that immediately adjacent to the Iowan border the waters from the melting ice would wash some of the sand and finer portions of the drift over the ice margin. However, the presence of occasional hills of loess, rich in fossils and the general absence of stratification planes in the deposits of sand along the moraine would indicate that even in the deposition of these materials the wind may have had a share.

Post-glacial Deposits.—Deposits of the Pleistocene later than those of the glacial series are found at numerous points over the county. An accumulation of peat occurs near the southeast corner of section 24 of Toledo township. This bog was formed by

*Calvin: Iowa Geol. Surv., Vol. VII. p. 89.

the deposits at the margin of the Toledo lobe of Iowan drift. It originally covered an area several square rods in extent. A thin stratum of peaty substance can be traced for some distance in the bank of a stream that has since drained this old marsh. It is covered by a few inches of soil that has washed down from the bordering hills. The peat bed is not of sufficient thickness to be of commercial value, but it is of interest as recording here a condition of things that has since passed away. It is said that when some weeds were being burned from this field in the autumn some years ago, the peat caught fire and continued to burn for several weeks.

The channels of all of the larger streams of the county are bordered by a wide belt of alluvium. Excavations in the flood plain of the Iowa river show about four feet of dark colored, fine-grained soil at the top, below which is a bed, twenty to thirty-three feet in thickness, which is composed of yellow clay, sand and gravel. This bed overlies the bowlder clay of the Kansan drift.

These deposits record a long interval after the Kansan drift was laid down in which the land stood higher than at present. During this period a wide valley was carved into the Kansan drift at least thirty feet deeper than the bed of the present river. The age of the sand and gravel deposit is not definitely known. It seems probable that the cutting was accomplished previous to the Iowan ice invasion, and that the subsidence which is thought to have attended the Iowan stage of glaciation resulted in the partial filling of the old pre-Iowan valley.

The same history is recorded in the valleys of all of the larger creeks of the county. These all flow in wide channels which are covered with deep deposits of alluvium. The broad bottom of the Iowa river in Tama county has an extent of almost one hundred square miles; while the flood plains of the creeks of the area would aggregate nearly as much more. These give to the county a large proportion of rich alluvial land.

Unconformities.

After the sediments which constitute the rocks of the Kinderhook stage were laid down, an upward movement of the earth's crust carried this portion of the state above the sea. During all of the remainder of the Lower Carboniferous epoch this was a land surface, subjected to erosion. The Upper Carboniferous epoch was initiated by a downward oscillation of the crust that permitted the sandstone of the Des Moines stage to be deposited unconformably over the eroded surface of the Kinderhook strata.

The elevation which brought to a close the deposit of the Des Moines sandstones was followed by an exceedingly long interval during which the area that now comprises Tama county was a land surface. It was probably toward the latter part of this interval that the deep preglacial valleys above described were carved into the strata of the Carboniferous system. The earliest ice sheet spread its mantle of drift unconformably over this preglacial surface and the materials of each successive ice sheet were left unconformably over the eroded surface of the preceding.

Preglacial Surface.

From a study of the well sections and the rock exposures of the area, it will be seen that the surface of the indurated rocks, before it was covered by the mantle of till, presented greater inequalities than occur over the area at the present time. The table of elevations shows that the maximum known difference in altitude between even the most remote points within the county is only 267 feet; while the difference in elevation between adjacent points, as valleys and uplands, scarcely ever exceeds eighty or ninety feet. The record of a well on the farm of W. B. Mitchell in Otter Creek township shows that the indurated rocks at that point are buried beneath 370 feet of superficial materials, while less than fifteen miles to the westward the indurated rock ledges outcrop in the bluffs to the top of the hills. The preglacial relief at points not more than a dozen miles apart was 100 feet greater than the present maximum difference in altitude of points separated by the entire length of the county.

There is evidence that the bed of the old river valley which passes beneath the town of Vining and on to Belle Plaine is at

least fifty feet deeper where it leaves the county than at the point in Otter Creek township where it was reached by the Mitchell well.

There is no doubt that the preglacial surface of Tama county was carved by the agents of erosion into deep wide valleys which were bordered by precipitous bluffs three to four hundred feet in height. This ancient topography must have presented features which resembled in many respects those of the driftless area at the present time. The leveling mantle of drift that was left by the successive ice sheets filled up these deep gorges and ravines so that the tops of the ancient hills are now but rarely seen.

Soils.

The soils of this favored area will always constitute the greatest source of wealth to the people of Tama county. The type of soil that occurs over the Iowan drift plain is the most distinctive and probably the most fertile of any in the county. It is deep and black, rich in carbonaceous material and contains an abundance of mineral matter in such compounds as can readily be utilized by growing plants. The surface over this area is fairly well drained, yet the slopes are not so steep that the soil becomes rapidly impoverished by the washing effects of hea rain storms. There is no waste land on the farms, every square foot of which can be put under the plow. Over Tama county the Iowan ice did not leave so many bowlders as it did over some other portions of the Iowan plain, hence the farmers here enjoy all of the advantages of the Iowan drift soil without the disadvantages that are present over the more thickly bowlder strewn areas. The handsome, well kept homes and the large commodious barns which characterize the farms over the Iowan plain attest the great productiveness of this recent soil.

Another type of soil is found over the loess covered Kansan drift portion of the county. The Kansan surface in Tama county is thoroughly drained. The soil is loose and porous, easily tilled and never becomes water clogged. Where the land is not too rolling this soil is dark-colored, rich in organic matter and fairly productive. On the steeper slopes and over the more or less sandy ridges which border the Iowan plain the more desirable

constituents of the soil are constantly removed by erosion so that the materials that contribute to the food of plants are not allowed to accumulate at the surface. When the earliest settlers came to Iowa they found this area covered with heavy timber. A few of the primeval trees may still be seen, surviving remnants of the splendid forests which at one time mantled these hills and valleys. The presence of a forest over the steeper slopes prevented the wasting of the soil through rapid erosion and preserved as the fertile leaf-mould the products of plant decay that were formed upon the surface. With the destruction of the forests, however, the chief conservator of soil fertility over these slopes disappeared. When subjected to constant cultivation they yield but meagre returns for the labor and expense involved in the production of the crop. The original forests should never have been removed from these areas, but where this has been done if the surface is allowed to become grass covered and the land devoted to purposes of pasturage the strength of the soil can be retained and the owner of the land will be assured of a fair remuneration for all the labor which he expends upon it.

A third type of soil occurs over the flood plains of the principal streams of the county. This alluvium is usually underlain by a bed of sand and gravel which gives it thorough underdrainage. It is deep and rich and mellow, containing the cream of the soil removed from the hills bordering the channel and from the slopes which are drained by the tributary streams. Where not too low so as to be in danger of inundation, and where there is not too large a proportion of sand present, this alluvium is a very productive soil ranking second to none in ease of cultivation and general fertility.

ECONOMIC PRODUCTS.

Tama county is pre-eminently an agricultural district. The products, like the quality of her soils, are rich and varied. An abundant yield of corn and oats and grass never fails to reward richly the intelligent tiller of the land. The agricultural possibilities of Tama county are not yet reached and it is in that direction that the people of this fertile area must largely look for the basis of their prosperity and progress.

Building Stone.

The total value of the output of building stone in Tama county for the year 1901 was $325.* The stone suitable for building purposes comes from the Kinderhook stage of the Mississippian series. As described above, it is limited to a small area in the middle western portion of the county. Of these rocks the beds that have been used embrace the oölitic limestone and the arenaceo-magnesian beds which immediately overlie them. The oölite is a weak stone crumbling rapidly when exposed to the air. When polished it presents a pleasing appearance and if used in places where it will be protected from the weather it proves a very satisfactory stone. These oölite layers were especially desired for the making of lime in the days when each locality was dependent upon its own resources for building materials. There is but little of this stone used at the present for any purpose. When the importance of good roads is better appreciated and permanent road beds come to be built over the area, this oölitic limestone will be a valuable deposit, easily accessible and producing good results when used for road making.

Samples of the oölite from Montour were tested by Mr. Logan Waller Page of the Road Material Laboratory connected with the U. S. Department of Agriculture. The results of the test are given below:

Specific gravity	2.61
Weight in pounds of a cubic foot	163.12
Pounds of water absorbed by a cubic foot	1.65
Departments coefficient of wear	60.4
French coefficient of wear	5.9
Percentage of wear	7.9
Cementing value	129.
Recementing value	43.

With regard to the use of this material in the building of roads Mr. Page says, "Although this rock has a low coefficient of wear, its cementing value is so high that excellent results should be expected on light traffic roads."

The magnesian layers of the bed overlying the oölite furnish a desirable quality of stone for rough foundation purposes. The material becomes harder after it has been taken from the ledge,

*Beyer: Iowa Geol. Surv., Vol. XII, p. 52.

the layers are of such thickness as to make them easily worked and the supply is almost inexhaustible over the very limited area in which it occurs.

The demand is local, as the quarries at LeGrand are more accessible to the railroad, making the facilities for shipping stone much better there than at any point within Tama county. Practically all of the stone produced in the county comes from these arenaceo-magnesian layers overlying the oölite. Its value for use as road material may be judged from the results of tests made upon stone from these layers at the Butlerville quarry.

The report of Mr. Page upon this stone is as follows:

Specific gravity	2.59
Weight in pounds of a cubic foot	162.19
Pounds of water absorbed by a cubic foot	3.21
Department's coefficient of wear	0.
French coefficient of wear	1.8
Percentage of wear	22.5
Cementing value	22.
Recementing value	34.

Relative to the above Mr. Page remarks: "This rock has too low a resistance to wear to warrant its use in macadamizing a road; but it has the peculiar property of recementing with increased strength and ought to make a good surfacing material." While in Tama county there are no deposits of gravel, which probably furnish the most desirable product for road making, yet there are materials suitable for that purpose in abundant quantities and close at hand. The oölite bed and the hard limestone layers which immediately overlie the aranaceo-magnesian bed in Tama county, and which are developed in greater thickness at exposures just across the border in Marshall, would, when crushed, make a good macadam. For surfacing material the beds that overlie the oölite would furnish a superior product in quantities almost unlimited.

Lime.

A number of years ago lime was burned on quite a large scale at Butlerville and at Montour. The beds of oölite were especially desired for that purpose. This limestone yields as good a quality of lime as can be made from the pure calcium carbonate and the materials for such a product occur at the above points in great

abundance. However, the lime made from dolomite is superior in value to the best that can be produced from the lime carbonate in that it does not yield so readily to the action of the atmosphere. It can be kept longer without injury and it sets into a harder and more durable plaster or mortar. The magnesian layers, as a general rule, contain too large a proportion of sand to produce the best results in lime making.

Sand.

Sand suitable for building purposes occurs at a number of places in Tama county. Large quantities are annually taken from the sand flats along the bed of the Iowa river. The sand hills of the Iowan moraine furnish unlimited quantities in the central portion of the county. Some of the more incoherent layers of the Kinderhook sandstone would furnish serviceable material for plaster if abundant deposits easier of access were not available.

Clay.

According to the statistics compiled by Professor Beyer on the Mineral Products of Iowa, the value of the clay products manufactured in Tama county for the year 1901 aggregated $63,500.* Brick and tile are the only clay products at present made within the area. The raw material is furnished mostly by the deposits of loess and alluvium. Factories are supported at various points over the county.

Toledo.—A brick and tile factory owned and operated by John Wild and son is located just west of town near the Chicago and Northwestern depot. The plant includes two drying sheds, 48x150 feet and 20x150 feet respectively, with drying space of 12,600 square feet. It is equipped with a thirty horse power Erie engine, a J. D. Fate brick machine, with a capacity of 25,000 brick per day, and a tile machine of the same make with a daily capacity of 10,000 three-inch tile. Various sizes of tile are manufactured, ranging from 3 to 8 inches n diameter. There are two up-draft kilns with a capacity of 180,000 brick, and one down-draft with a capacity of about 55,000. The plant is in operation

*Beyer: Iowa Geol. Surv., Vol. XII. p. 49.

about nine months of the year, during the greater part of which time ten men are employed. The most of the brick and tile are sold to farmers and builders within a radius of eight or ten miles. The total value of the output of brick per year is about $7,000, while the value of the tile production is about one-fourth of that amount. The clay used at this place is a loess alluvium about eight feet in depth which occurs along the valley of Deer creek.

Tama.—About one mile east of Tama, in the southwest quarter of section 25 of Tama township, there is a brickyard owned and operated by C. B. Bentley and son. This factory is equipped with a forty horse power engine and a Brewer tile and brick machine with a capacity of 25,000 to 30,000 brick per day. There are two up-draft kilns, a drying shed 80x100 feet and a machine building 40x60 feet. This plant is in operation about six months of the year. The value of the brick output for the year is $6,000

Fig. 31. Typical view of the level Iowan plain in the northern part of Tama county.

to $7,000. The material is mostly sold in Tama and the surrounding district within a radius of a few miles. The clay pit is in a bed of fossiliferous loess about twenty feet in depth which occurs on the north bank of the Iowa river.

Gladbrook.—Two large plants for the manufacture of clay products are operated at Gladbrook. The works of the Gladbrook Pressed Brick and Tile Company are located about one mile west

[illegible]

[illegible] gorges, the whole surface profoundly trenched and carved by erosion so as to expose rock sections scores or even hundreds of feet in height almost everywhere. To one not personally familiar with the facts, the contrast between the driftless area and the country we are considering is almost inconceivable: for Chick-

power Atlas engine and a J. D. Fate stiff mud machine which by changing dies and table is used for either brick or tile. There are two round down draft kilns with a separate capacity of 60,000 brick. The standard sizes of tile, three, four, six, eight and ten inches in diameter, are produced. The plant employs about a dozen men during nine months of the year. The total value of the yearly output of tile is $3,000 and of brick $7,000. Their market is chiefly in and about Traer.

Water Supply.

The Iowa river furnishes an abundant supply of water to the area through which it flows. The larger creeks all head in the marshy sloughs of the Iowan drift plane. These springs dole out to the surface streams a supply of water, clear and constant, which continues to flow throughout the year. Abundant water is furnished by shallow wells from the porous beds of the Pleistocene in almost every part of the county. Flowing wells are obtained by penetrating the gravel bed of Aftonian age which underlies the Kansan drift along a deep preglacial valley in the southern portion of the area. Sometimes the water supply seems to come from the indurated rocks adjacent to this bed of gravels. It seems likely, however, that even in such places this porous deposit is the real source of the accumulation of the water which probably fell upon the surface some miles to the northward.

ACKNOWLEDGMENTS.

The writer is glad for this opportunity to acknowledge the kindness of many persons who rendered assistance during the prosecution of the work set forth in the preceding pages. Thanks are especially due to the director of the Survey, Professor Calvin, for counsel and help; to Mr. William Westfall of Toledo, and Mr. Clyde Stauffer of Gladbrook for assistance in the collection of data, and to many others whose interest in the work was unfailing, and whose service was limited only by their opportunity. To all of the above the author wishes to express his high appreciation of their service and tender his sincere thanks.

GEOLOGY OF CHICKASAW COUNTY.

BY

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CONTENTS.

INTRODUCTION.

GEOLOGIC AND GEOGRAPHIC RELATIONS—AREA.

Chickasaw county, one of the altogether too few geographical divisions which bear a name derived from the speech of the aboriginal inhabitants, is located in the northeastern part of the state. Howard county separates it from Minnesota, Winneshiek and Fayette bound it on the east, Bremer on the south and Floyd on the west. With respect to its indurated rocks, Chickasaw is wholly included within the Devonian area; so far as concerns its surficial deposits, it lies within the area occupied by Iowan drift. Its eastern boundary is located only a few miles west of the eastern edge of the Iowan plain, and as a result of its position our county embraces some of the sandy ridges, loess covered uplands and other marginal topographic characteristics of the Iowan area. There is only the width of two counties separating Chickasaw from the deep valley and the steep, rocky, picturesque bluffs of the Mississippi river; and much less space intervenes between our county and the driftless area with its streams flowing in deep gorges, the whole surface profoundly trenched and carved by erosion so as to expose rock sections scores or even hundreds of feet in height almost everywhere. To one not personally familiar with the facts, the contrast between the driftless area and the county we are considering is almost inconceivable; for Chick-

asaw county is an area of practically no rock exposures, it is a level plain, uneroded, in most of its area very imperfectly drained so far as being provided with natural trenches for carrying off storm waters is concerned. The area of Chickasaw county is approximately 500 square miles.

PREVIOUS GEOLOGICAL WORK.

The geologists of a generation ago gave very scant attention to the drift, or to any of the numerous problems connected with the surficial deposits. From the standpoint and attitude of that day these subjects were all negligible quantities which seemed scarcely to fall within the scope of geological science. For it must be remembered that geology was then confined almost exclusively to an investigation of the indurated rocks, of the sedimentary rocks chiefly—such as limestones, sandstones and shales—together with their fossil and mineralogical contents. With most of the prominent geological workers of the time there seemed but one sure way to win geological renown, and that was to describe new fossil species. When, therefore, it is borne in mind that more than nine-tenths of Chicaksaw county is simply a great prairie plain presenting nothing for investigation but such commonplace things as rich black soils and erratic crystalline bowlders, that exposures of native rocks are very few, and none of commanding interest from the point of view of the elder geologist, it will not seem strange that this county is scarcely mentioned in our geological literature. It was with reference to an area in northeastern Iowa, of which Chickasaw county is a typical part, that our pioneer geologist, Dr. David Dale Owen, wrote in his report to the Commissioner of the General Land Office, in 1848:—"The geologist who undertakes to investigate the vast prairie country of the Mississippi Valley must be provided with no common share of patience and perseverance. He must be content to travel for half a day together without seeing aught but a rich, black soil, covered, as far as the eye can reach, even down to the very edge of the small streams, with a thick and high growth of prairie grass, with perhaps a faint outline of timber cutting the distant horizon. He must be prepared to wade swamps, to ford streams waist deep, or, in times of freshets, to plunge in and

breast the current. He must not shrink beneath a broiling sun, without even a bush to cast a faint shadow over an occasional resting-place. He must think himself fortunate if he can reach, at night, a few scattered oaks to plenish his fire, and boil his camp kettle; and he may consider it a special instance of good luck, if, in return, he can catch a glimpse of a rock exposure once or twice a day. He may travel for days together without lighting on any object more interesting than the hillock of the prairie dog, or the broad lair of the bison."*

The conditions under which the work of D. D. Owen was done have long since disappeared. The aspect of the country has been greatly changed. Groves, everywhere, within the limits of the horizon, break up the wideness and monotony of the sea-like expanses of level prairie, fringes of planted trees afford grateful shade by every wayside, while improved roads and well constructed bridges relieve the traveller almost wholly from the necessity of wading marshes or fording streams. Many of the marshes, by well planned drainage, have indeed been transformed into fruitful fields. But amid all the transformations which have taken place since Owen worked and wrote, the scarcity of rock exposures remains practically unchanged. In Hall's report on the Geology of Iowa there is the barest reference to Chickasaw county, and that relates altogether to the drainage and surface characteristics.† White's report‡ does not even mention our county in any way. As a matter of fact, however, the serious limitations of time under which he worked prevented his visiting any of the prairie counties in northeastern Iowa. In McGee's Pleistocene History of Northeastern Iowa§ there are references to the topography and other surficial phenomena of Chickasaw county. In no official publication, however, has there heretofore been any discussion of the interesting though numerically limited rock exposures which the county affords.

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*The quotation is copied from Owen's Geol. Sur. of Wis., Iowa and Min., p. 79; Philadelphia, 1852. The wording is but slightly different in the original report to the Commissioner of the Land Office, pp. 86 and 87; Washington, 1848.

† Rept. on the Geol. Surv. of the State of Iowa, by James Hall and J. D. Whitney; Vol. I, Part I, p. 306. 1858.

‡ Rept. on the Geol. Surv. of the State of Iowa, by Charles A. White, M. D.; Vols. I and II. Des Moines, 1870.

§ The Pleistocene History of Northeastern Iowa, by W J McGee; Eleventh Ann. Rept. of the U. S. Geol. Surv.; Washington, 1891.

PHYSIOGRAPHY.

TOPOGRAPHY.

The topography of Chickasaw county shows few striking features of any kind. In general the surface is a plain modified by only a small amount of relief. With the exception of some small areas in the western part of Bradford and Chickasaw townships, the whole county is covered with the Iowan drift which remains unaltered and uneroded, precisely as it was left at the time of the withdrawal of the Iowan glaciers (Fig. 22.). In places the Iowan drift mantle was thick enough to disguise the pre-Iowan topogra-

FIG. 32. Level Iowan plain with characteristic bowlders, southwest quarter of section 18, Dresden township.

phy and develop the typical, gently undulating Iowan plain. In places the latest drift was too thin to do more than slightly modify the older, erosional topography. An unusual number of streams traverse the county—the general trend being from northwest to southeast—and divide the surface into a corresponding number of long, narrow inter-stream areas. The streams follow

broad, shallow troughs in the surface, in places two, three, or four miles in width. The narrow divides between the broad valleys vary in topographic types from areas of pronounced hills and swells and minor irregularities, to upland plains diversified by only low, flat, long-sweeping undulations. The typical Iowan plain is exemplified in the northern part of the northern townships, Deerfield, Washington, Jacksonville, and Utica. New Hampton is located in the center of such a plain, and the same type of plain surrounds Ionia, stretching away to the horizon in nearly every direction. The gently undulating plain, developed by the constructive and moulding effects of glacial ice, and not by erosion, is the predominant type of topography throughout the county. There are a number of areas, especially in the eastern part of the county, so level that drainage is still very imperfect, and crops suffer accordingly when seasons are more than usually wet.

The hilly, rolling tracts are never very extensive, but they are met with more or less frequently in every part of the county. Such tracts have no definite boundaries, for, in very short distances sometimes, they fade out and blend into the characteristic Iowan plain. One of these belts of rolling country occurs two or three miles south and southeast of New Hampton. For a mile and a half east of Fredericksburg there is a low, level plain, and this is followed by an upland area broken into rounded hills which, in some instances, rise sixty feet above the intervening depressions. From such a station as the southeast corner of section 9, Fredericksburg township, the contrast between the low plain and the billowy upland is very strikingly illustrated. A score or more of similar examples might be given. There are, for instance, a few sections of rolling Iowan in the northeastern part of Bradford township and contiguous parts of Chickasaw. The northwestern and western parts of Richland township are comparatively level, but the surface breaks into rolling swells along Calamus creek, while a third phase of the Iowan topography is illustrated in the broad, flat bottom land, partly undrained, which borders the Wapsipinicon river a little farther east in the same township. The rather feebly developed hilly characteristics of the rolling Iowan are still further exemplified in the southeastern

FIG. 33. Border of a small area of "rolling Iowan" in the southwest quarter of section 15, Jacksonville township.

corner of Jacksonville township and the adjacent parts of New Hampton. But these may suffice for concrete illustrations of a type of topography easily recognized and quite widely distributed (Fig. 33). The hills in such areas are not high, the surface slopes are comparatively gentle, the topography has not been developed by erosion since the Iowan drift was deposited, neither can it be claimed that it is simply a modification of a pre-Iowan surface. Like the more level plains into which this type merges, it is a product of constructive agencies, of ice moulding.

In some parts of the county the pre-Iowan topography is but imperfectly concealed by the later drift. An area of this kind makes up the long slope between Devon and the Little Wapsipinicon river at North Washington. There was here deposited only a very meager amount of Iowan drift; the rain-cut gullies by the roadside reveal the leached and oxidized Kansan till and the ferruginous Kansan gravels within a few inches of the grass roots; the undulations of the surface are much stronger than in typical Iowan areas; the hills and trenches of the old eroded Kansan are clearly expressed in the modern topography. Another interesting bit of erosional pre-Iowan topography is seen along the line

which separates sections 20 and 29 in Bradford township, on the east side of the Cedar river, opposite Nashua. A rather deep ravine with short lateral gulches, preglacial as to age, is cut in the Devonian limestones. Over part of this area all drift is absent, the rock coming practically to the surface as shown in figure 34. On both sides of the Cedar river, from the point where this

FIG. 34. Quarry in the southeast quarter of section 20, Bradford township, showing absence of drift in a small area of pre-Iowan topography.

stream enters Bradford township to where it leaves the county near Pearl Rock, there is a general absence of drift of any age, the Devonian limestones crop out on the slopes and hill tops in numerous places, the hills and ravines, with reliefs of fully eighty feet, are a product of preglacial erosion working on the indurated rocks. In the angle between the Cedar river and the Little Cedar, near Bradford, there is a high, steep-sided promontory not drift-covered, a conspicuous illustration of some of the characteristics of the preglacial topography. On the west side of the Little Cedar river, between Bradford and Bassett, there is very little Iowan drift; there are places where there is practically no drift of any kind; the topography is of the older erosional type. A region of sandy and partially loess-covered hills sixty to eighty

feet in height, well carved by surface drainage, occurs in sections 16, 17, 20 and 21, Chickasaw township. There are deep trenches of recent erosion along the roadsides, and there are some rain-cut scars and gulches in the fields; but in general the topography is old, older than the Iowan stage of glaciation. In the northeastern part of the town of Bassett there is a prominent knob-like hill which is the south end of a narrow ridge jutting out from the upland Iowan plain and encroaching upon the low, broad valley of the Little Cedar river. The bluffs bordering the river valley rise to the same general level. The whole surface of the region—bottom lands, bluff slopes and upland plains—is sprinkled with Iowan bowlders. The Iowan ice was here, but the amount of detritus it carried was insufficient to affect in any notable degree the relative altitudes of the pre-Iowan bluffs and low lands.

In a region as level and monotonous as is Chickasaw county in general, the shallow stream valleys become marked features of the topography. Over most of the county these valleys are simply broad concave sags in the general surface; but the valley of the Cedar throughout its short course in Chickasaw, and the valley of the Little Cedar from above Bassett to its confluence with the larger stream, are evidently old, rock-cut, preglacial trenches bounded by bluffs and hills rising to heights of eighty feet or more. Very little of the material from any of the drift sheets covering the adjacent parts of the country found permanent lodgment in these valleys. Between the town of Chickasaw and Nashua the broad bottom lands through which the Little Cedar flows are underlain by a heavy body of the valley phase of the Buchanan gravels, showing that the valley was as wide and deep as it is today at the time of the melting of the Kansan ice. There has been no filling and re-excavation of these valleys since pre-Kansan time. Some ox-bow lakes or abandoned meanders in sections 4 and 9 of Bradford township, practically at the present level of the river, indicate that there has been no deepening of the valley in very recent periods. Above and below Jerico, in sections 28, 31 and 33 in the northern part of Jacksonville township (Tp. 97 N., R. XII W.), Crane creek flows in a broad, ill-drained bottom land which is set off from the drier upland by an imperfectly defined terrace slope. The terrace is composed of valley

gravels of the Buchanan stage. In this region there has been some erosion of the gravels in the long intervals since their deposition, deepening the valley in which the stream meanders, probably to the extent of eight or ten feet. There is a small amount of rock cutting in the valley of the Little Turkey river, beginning one-half mile above Little Turkey post office and continuing at intervals to where the stream leaves the county. This feature is most marked a short distance east of the center of section 25 in the southern part of Utica township.

In other parts of the county, as already indicated, the streams flow in broad shallow sags in the drift and do not differ from the ordinary valleys of the Iowan plain. A number of branches of the Wapsipinicon converge in the southern part of Dayton township, and hence there is here an unsually large area of low, flat land, some of it showing ponds, and all of it imperfect surface drainage. There are here, however, as usual along all the streams, extensive valley trains of Buchanan gravel, and these afford perfect underdrainage to quite a large part of the area, and render its cultivation possible even in the wettest of seasons.

DRAINAGE.

The great number of streams traversing the county from northwest to southeast and dividing the surface into a correspondingly large number of long, narrow inter-stream areas, has been previously noticed. The Cedar and the Little Cedar drain the southwestern part of the county; the wide central belt extending from northwest to southeast, is effectively drained by the numerous branches of the Wapsipinicon; while Crane creek and the Little Turkey river carry off the surplus waters from the northeastern area. All the main drainage courses, as is clearly indicated by the general presence of accompanying valley trains of Buchanan gravel, were outlined as early as the melting stage of the Kansan ice; while the deep, rock-cut valleys of the Cedar and the Little Cedar were partially or wholly developed in preglacial time.

Altitudes.—The following table, showing the relations of a number of the more important points in the county to sea level, is compiled from Gannett's Dictionary of Altitudes:

	FEET
Alta Vista	1,155
Devon	1,194
New Hampton	1,155
Fredericksburg	1,075
Nashua	981
Lawler	1,078
Bassett	1,017

An examination of the table reveals the interesting fact that though the direction of the streams is toward the southeast, the general slope of the county is toward the southwest. Fredericksburg, located in the valley of a branch of the Wapsipinicon, is 94 feet higher than Nashua, almost directly west of it in the valley of the Cedar; and Lawler, in the valley of Crane creek, is 61 feet higher than Bassett, which is in the same latitude in the valley of the Little Cedar. The high points, Devon and New Hampton, are located on one of the long, narrow dividing ridges.

This general slope of the surface toward the southwest is not peculiar to Chickasaw county, it is characteristic of the major part of all northeastern Iowa. The country rises toward the northeast until the high points within a few miles of the Mississippi river, such as Iron hill near Waukon, attain an altitude of 1,300 feet above the sea. This anomalous behavior of the streams in flowing, not with the slope, but at right angles to it, was years ago pointed out by McGee in his Pleistocene History of Northeastern Iowa.*

STRATIGRAPHY.

SYNOPSIS.

The geological formations exposed in Chickasaw county are few in number. They are limited to two systems, the Devonian and the Pleistocene. The indurated rocks may all be referred to the Cedar Valley stage of the Middle Devonian series; the surficial clays and soils accessible to observation belong almost exclusively to the Kansan and Iowan stages of the Glacial series. The pre-Kansan drift exists, without much doubt, in its proper place at the base of the Pleistocene deposits, but its presence is not positively known. It is justly inferred, however, from the

* Eleventh Ann. Rep., U. S. Geol. Surv., pp. 363-365.

fact that a forest bed is encountered, interstratified with glacial deposits, in drilling deep farm wells in various parts of the county.

The stratigraphic relations of the formations which are open to direct investigation in Chickasaw county, may be conveniently indicated in tabular form as follows:

GROUP.	SYSTEM.	SERIES.	STAGE.
Cenozoic.	Pleistocene.	Glacial.	Iowan.
			Kansan.
Paleozoic.	Devonian.	Middle Devonian.	Cedar Valley.

Devonian System.

General Discussion.—So far as known the Devonian limestones underlie the Pleistocene deposits over the entire region now under consideration. Chickasaw county, however, is so generally and so completely covered with glacial drift that rock exposures are very few in number and very widely scattered. There is one very obscure outcrop of Devonian limestone on Crane creek, and two or three, somewhat more satisfactory, occur on the Little Turkey river in the southeastern part of Utica township. All the other outcrops are in the western part of the county, and the most important of these are confined to the valleys of the Cedar and the Little Cedar rivers. In seven townships out of the twelve there is not a single exposure of native rocks in place, and over almost the whole area of the remaining five, the surface is fertile prairie with the native Devonian beds concealed by deep deposits of drift.

The strata exposed in the county range from the horizon of *Gypidula comis* and *Spirifer pennatus*, the equivalent of the quarry beds at Independence, to the horizon of the yellow, magnesian limestones which lie above the Acervularia and Stromatopora zones and form the uppermost members of the Devonian sections in Buchanan and Howard counties. The beds are more or less magnesian throughout the entire section, and some parts

of the section are so completely dolomitized as to resemble certain phases of the Niagara limestone in the counties of Delaware and Dubuque. The resemblance to the Niagara is heightened when, as occurs in a quarry nearly opposite the mill at the town of Chickasaw, the heavy, dolomitized beds include great numbers of chert nodules and are separated one from the other by thick bands of chert. In nearly all the exposures of the Devonian in this county the limestone is soft, earthy, granular and non-crystalline, and vug-like cavities lined with calcite are common. In quarrying some of the beds the lining of calcite becomes detached from the wall of the cavity in which it was deposited and furnishes an example of a thin-walled, calcareous geode.

Typical Exposures.—Gypidula comis Beds, the lowest beds recognized in the county are seen in the east bluff of the stream,

FIG. 35. Quar y in cherty dolomitic beds at the *Gypidula comis* horizon, a short distance above the bridge at Chickasaw.

a few rods above the wagon bridge at Chickasaw (Fig. 35). There is a section of twenty-five feet here exposed. The rock is a heavy bedded dolomite which is much broken up toward the sur-

face on account of weathering. Lower down the beds are intersected by numerous joints. A large amount of chert in streaks and bands—the chert sometimes included in the layers, in some cases occurring as partings between them—is a striking feature of this section, and one very unusual in the Devonian. Lithologically and otherwise the rocks resemble very closely many exposures of the Niagara in Delaware, Jones and Dubuque counties. At first sight it seemed scarcely possible that such rocks could belong anywhere except in the Niagara; but, while fossils are absent from most of the beds and are scarce in all of them, it was found that the lower ledge, about three feet in thickness, contained many perfect casts of *Gypidula comis* Owen, and *Spirifer pennatus* Owen. These species establish the Devonian age of the beds beyond question and make it possible to correlate them with the beds in the City quarry and the lower part of the O'Toole quarry at Independence. The differences, however, in the character of the stone and in the firmness and thickness of the individual layers at the two points, Chickasaw and Independence, are surprisingly great. The beds described above crop out at intervals for some distance along the bluff, above and below the quarry shown in figure 35, and they have been cut through by a deep ravine which traverses the southeast ¼ of section 16, a short distance north of the quarry.

On the west side of the river, about a mile above the bridge at Chickasaw, beds of about the same horizon as those in the Chickasaw quarry are exposed in a ravine, near the level of the water in the stream, not far from the middle of the north line of the southwest ¼ of section 16. Quite an amount of building stone has been taken out at this point and the locality is known as the Huffman quarry. The stone is magnesian, but is not so perfectly dolomitized as at Chickasaw. The layers are thinner and the fossils, instead of occurring as mere casts, have the shells preserved. The finely striated Independence type of *Atrypa reticularis* is common, and there are some specimens of *Spirifer pennatus,* a form always associated with the preceding at the typical outcrops in Buchanan county.

Atrypa occidentalis Beds. Beds a little higher in the geologic column than those described in the preceding paragraphs, are

seen in the old Bishop quarry (Fig. 36), in the northeast ¼ of section 16, Chickasaw township. The stone, as usual in this part of Iowa, is highly magnesian and lies in thin, even layers which may be quarried in flagstone-like pieces two to six inches in thickness. There are numerous cavities lined with calcite, and some very

FIG. 36. The old Bishop quarry at the horizon of *Atrypa occidentalis*. The Acervularia beds are seen at the top of the section.

perfect and symmetrical calcareous geodes may be obtained as a result of the separation of the calcite lining from the walls of the cavities. The fossils are of the types found toward the upper part of the quarries at Independence, and include along with *Atrypa reticularis* and *Spirifer pennatus,* such forms as *Orthis iowensis* and Hall's occidental variety of *Atrypa aspera.* The beds are cut by oblique, parallel joints, shown in figure 36, and along the joints the fossils are often well exposed by solution and removal of the matrix.

Acervularia profunda Beds. This zone occurs at the top of the Bishop quarry as it does in most of the quarries at Independence, overlying the *Atrypa* and *Spirifer pennatus* zones. Besides the typical species, *Acervularia profunda,* this zone contains *Cystiphyllum americanum, Favosites alpenensis, Cladopora prolifera*

and a number of the coarse stromatoporoids which are associated with these species at the same geological horizon at Littleton in Buchanan county. Here, as at Littleton, the *A. profunda* shows a conspicuous tendency to independent growth of the corrallites. The quarry exposes a section twenty feet in thickness. The upper two and a half feet are occupied by the Acervularia zone, which in places is crowded with the corals and stromatoporoids mentioned. Some of the stromatoporoids, weathered to show perfectly the concentric, laminated structure, are more than a foot in diameter.

The beds immediately below the Acervularia and stromatoporoid horizon are quarried and burned for lime in the town of Chickasaw, at a point thirty-five feet higher than the base of the quarry in the river bluff near the mill. The Acervularia zone is included in the stripping. The corals are large and coarse. Stromatoporoids are most common; but Acervularia, Cystiphyllum, Zaphrentis, Cyathophyllum, and a form that is probbaly Craspedophyllum are also present. The corals are all more or less silicified, and the entire zone is useless for lime burning.

The Acervularia horizon, noted above, is indicated in the pits made for the foundations of the new railway bridge at Nashua. Among other species recognized in the loose materials thrown out in making the excavations were *Acervularia profunda, Stropheodonta demissa* and *Orthis iowensis*. Below the Greenwood mill, one mile northeast of Nashua, loose fragments of rock evidently washed out of the river bed by the plunge of water over the dam, contained a number of stromatoporoids besides *Acervularia profunda, Craspedophyllum strictum, Atrypa reticularis, A. aspera*, and other types belonging to the horizon of the quarries at Chickasaw. The beds which at Chickasaw are at least thirty-five feet above the river, are at Nashua and Greenwood mills below the level of the water. The slope of the valley, ascertained by comparing the altitude of Nashua with that of Bassett, is about four and one-half feet to the mile. From Chickasaw to Nashua the fall should be about twenty-seven feet. Between these two points the Acervularia zone has descended from at least thirty-five feet above, to five feet below the level of the water, making a total dip to the strata of about eleven feet to the mile.

Spirifer parryanus Beds. Above the mill dam at Nashua there are exposures in the right bank of the Cedar river showing a section twenty-five feet in thickness. The layers are not all well exposed, but so far as they could be observed they are soft, earthy dolomite. The lower part of the section is quite barren of fossils, but twenty feet above the level of the water there are a few layers rich in casts of *Spirifer parryanus* Hall. At Littleton, Iowa, the *S. parryanus* horizon is not more than five or six feet above the *Acervularia profunda* beds; at Nashua the two horizons are separated by more than twenty feet of comparatively barren strata. While in the river bluff at Nashua the fossils appear only as casts, there is evidence that non-dolomitized beds of this horizon must outcrop somewhere in the neighborhood. In making a small culvert in one of the streets of the city, slabs of a comparatively pure limestone were used, in which the crowded shells of *Spirifer parryanus* are perfectly preserved. Information as to where the stone came from could not be obtained; but great variations in the lithological characteristics of any given stratum, within very short distances, are by no means unusual. The *S. parryanus* beds descend to the level of the water at Pearl Rock, three miles south of Nashua, the dip south of the city being essentially the same as that from the north, eleven or twelve feet to the mile.

Idiostroma Beds. In a ravine a short distance north and west of the Thomas school house, in the southeast ¼ of section 30, Bradford township, there are two parallel ridges or reefs of the coarse-stemmed Idiostroma which occurs from ten to fifteen feet above the *Spirifer parryanus* horizon in Johnson county. These reefs are curiously local affairs. Each one is only thirty or forty feet in width, thickened in the middle and thinning out at the edges. They are about twenty yards apart, and their trend is northwest-southeast. They are underlain and overlain by soft, earthy dolomite, the overlying beds arching over the ridges, dipping in between them, and coming on each side in contact with the underlying beds. They seem to be simply elongated lenses of reef material with no very great extension in any direction. On the west side of the ravine, a little below the point where the reefs occur, there is a good section which includes both the underlying and the overlying beds, but it shows no trace whatever of the

Idiostroma material. The whole body of the reefs has been altered more or less to a very hard, light-colored, siliceous dolomite, very different in texture, color and composition from the soft, granular beds prevailing in this vicinity. The surface of the tangled mass of Idiostroma stems is covered in places with a thin coating of quartz, and in the more compact portions of the mass, minute quartz crystals line the surface of cavities from which fossils have been dissolved. In addition to the Idiostroma, which is the common and typical fossil, there are occasional specimens of *Acervularia davidsoni.* A Favosites, probably *F. alpenensis,* occurs more frequently. *Euomphalus cyclostomus* Hall, a form always associated with Idiostroma in Johnson county, and a slender Orthoceras six or eight inches long, are among the other observed fossils. The great alterations which the reef material has undergone, has made specific identification of the unsatisfactory casts by which fossils are mainly represented, in some cases practically impossible. While these local ridges of Idiostroma and associated fossils are in their proper stratigraphic relations to the other known life zones of the Devonian, it is quite evident that this particular area was never occupied by a living Idiostroma reef such as once covered the region now known as Johnson county. Such reef material does not appear anywhere else in Chickasaw county, although there are many sections, some, as noted above, within even a few rods of the locality described, which embrace strata from geologic levels both above and below the reef horizon. At present there is no known point nearer than the northern part of Johnson county where this peculiar stromatoporoid on a reef-making scale flourished in place. The very limited extent of the Idiostroma lenses, their relations to the regular sediments of the region, and their lithological differences from the local strata, all suggest that the relatively small amount of material they represent was brought here from probably long distance by some marine agent of transportation.

Lithographic Beds. At Iowa City there are beds of fine-grained, light-gray lithographic limestone beginning a few feet above the Idiostroma horizon. Similar beds have been noted in this volume above the equivalent of the *Acervularia davidsoni*

zone in Howard county. They occur in the same geological position at numerous other points in Iowa. They are present on the hill tops about Nashua in Chickasaw county. There are no sections in this county that show the lithographic beds well, but some weathered ledges in place and numerous loose fragments may be seen on the high points in the roads leading north and south from Nashua.

Intermediate Beds. To horizons somewhere between the *Spirifer parryanus,* and the lithographic beds should be referred the exposures in the northern half of Deerfield township. The entire absence of fossils here makes exact correlations difficult, but the lithological resemblance of the beds to the thin layers in the upper part of the Croft quarry at Elma in Howard county, coupled with the fact that the Deerfield exposures are distant from Elma only a few miles, would justify the reference of these beds to the horizon of the upper part of the Elma quarries, or to one slightly higher. As a matter of fact beds corresponding to those in the upper part of the Elma quarries have been worked four miles southwest of Elma, within less than two miles of some of the exposures in Deerfield township, Chickasaw county. By reference to the Howard county report it will be noted that the *Spirifer parryanus* zone is present in the bottom of the Croft quarry, and hence the beds in question lie between this zone and the horizon of the lithographic limestone.

In the southeast ¼ of section 3, Deerfield township (Tp. 96 N., R. XIV W.), on land belonging to Edward Brown, stone has been quarried somewhat extensively to meet the local demand. The beds are thin, yellowish, argillaceous, and without fossils. Toward the bottom of the quarry the bedding is quite irregular, and below the bottom as it appears at present, from a pit now filled with mud, there were formerly quarried a few ledges of hard limestone, six to eight inches in thickness. There are here two openings a short distance apart. In both there is quite a strong dip toward the southwest. In the one farthest east the following section may be made out:

		FEET.
7.	Black loam mixed with weathered fragments of limestone	2
6.	Thin-bedded, earthy limestone, badly weathered, becoming thicker toward the west end of the quarry	3
5.	Band of harder, purer, drab-colored, crystalline limestone which is not affected by weathering	$\frac{2}{3}$
4.	Thin-bedded zone which disintegrates into a light yellow, marly clay mixed with concretionary nodules	2
3.	Thin, laminated, argillaceous beds, yellow in color, containing some fine siliceous grit	4
2.	Harder, dark gray beds which now form the floor of the quarry, layers six to ten inches in thickness, dipping southwest, upper surface irregular and uneven	2
1.	Heavy, hard beds, not now exposed, but were formerly qurried over a small area	3

A few rods to the southwest is the second opening which includes the same beds as the quarry just described, and shows in addition some firm beds of good quality above No. 6 of the preceding section. A mile and a half north of the Brown quarry, near the middle of the south line of section 27, Tp. 97 N., R. XIV W., on land of John W. Kane, there is a quarry which shows a series of beds probably equivalent to those above No. 6 in the second opening on the land of Mr. Brown. Some of the layers are hard, bluish in color, and from two and a half to three inches in thickness. In general the beds are thin, but toward the bottom of the exposed section there are some four-inch courses which may be made to serve a good purpose for such masonry as the neighborhood requires. Two miles farther north, near the middle of the north line of section 22 of the same range and township, the Tierney quarry is opened in a knob-like, stony point. The stone is the same as at the Kane quarry. Very little work has been done here in recent years.

To the same horizon as the exposures in Deerfield township, should probably be referred the two quarries which have been opened in section 4, Chickasaw township. One of these is in the northeast, and the other in the northwest $\frac{1}{4}$ of the section. The greatest amount of work has been done in the northeast quarry. As usual at this horizon, in this part of the state, the beds are thin. They are quite magnesian, but not truly dolomitic. Toward

the bottom the layers are thicker and stone of fair quality may be obtained. The strata are here cut by two systems of joints trending nearly east-west and north-south. As in all the magnesian beds of the region, there are some cavities lined with calcite.

The exposures so far discussed under the head of *Intermediate Beds,* are all on high ground as compared with those in the river valley at Chickasaw and farther south, but at an altitude from thirty to forty feet above the level of the river, in the southeast ¼ of section 20, Bradford township, there are two openings belonging to the Intermediate Beds. These probably lie a little below the floor of the Brown and Kane quarries in Deerfield township. One of these openings is shown in figure 34. The beds are thin in the upper part of the exposure, but there are some heavier ledges near the base. All the layers are more or less magnesian. Formerly these quarries were regularly worked, and some of the firmer and purer beds were burned into lime, but no work has been done here in recent years. What is known as the Allen quarry, two and three-fourths miles northwest of Nashua in Floyd county, is operated in these same beds, and from this the following detailed section is obtained:

		FEET.
6.	Thin-bedded limestone, the courses varying from one to five inches in thickness, some layers soft and granular, others hard and fine-grained.....	8
5.	Some firmer courses, six inches in thickness......	2½
4.	An eight inch ledge of good building stone......	⅔
3.	A firm fourteen inch ledge	1⅙
2.	A twelve inch ledge................	1
1.	Heavy stone suitable for bridge work............	1½

The order of succession is partly obscured by waste and weathering in the quarries in section 20 east of Nashua, but so far as it could be determined it is identical with that in the Allen quarry. There are few recognizable fossils at either of these points, the only forms seen were casts of *Atrypa reticularis* in the lower heavy ledges. Stone of the fine-grained, lithographic type crops out in the road about half way between Nashua and the Allen quarry.

The Upper, Yellow, Magnesian Beds. In the northwest corner of the town plat of Nashua, there are heavy, dolomitic layers above

the level of the lithographic stone seen in the road a short distance to the northwest. This is evidently the equivalent of the thick, magnesian layers in the upper part of the Salisbury quarry and the other quarries about Vernon Springs and Cresco, described in the report on Howard county, the equivalent also of the yellow magnesian beds quarried in the river bluffs above Littleton in Buchanan county, and of the beds quarried near Raymond in Blackhawk.

These beds are not well developed in the western part of Chickasaw, but they are seen to fairly good advantage on the other side of the county. The best and practically the only section in this region occurs in the west bluff of the Little Cedar river, near the center of section 25 in the southern part of Utica township. There is here a section ranging from fifteen to twenty feet in thickness. The rock is checked by numerous joints, the thickness of the beds varies from six or eight, to twenty inches, or even more. The rock is soft, yellow, magnesian, but durable and capable of affording a fair quality of ashlar and dimension stone. It has the concretionary or concentric iron staining of the corresponding beds in eastern Howard county, and there are the same vug-like cavities with calcite lining Some impressions of coarse-ribbed Atrypas occur in some of the beds near the top of the section. At the bridge a short distance west of Little Turkey postoffice the same beds are exposed, and there are other exposures one-fourth of a mile above the bridge. Only one exposure was noted on Crane creek, and that was in the northwest 1/4 of the northwest 1/4 of section 13, Jacksonville township. Weathered fragments of a soft, magnesian limestone were all that could be seen. It is probable, however, that the horizon is the same as that of the beds on the Little Turkey in Utica township.

GENERAL DEVONIAN SECTION.

The probable thickness of the several members of the Devonian section in Chickasaw county may be expressed as follows:

		FEET.
7.	Upper magnesian beds	50
6.	Lithographic beds	10
5.	Intermediate beds	25
4.	Idiostroma beds	5
3.	Parryanus beds, and down to next division	25
2.	Acervularia beds	5
1.	Gypidula, and Atrypa beds, up to Acervularia zone	45

Pleistocene System.

KANSAN STAGE.

Kansan Drift.—There is reason to believe that the Kansan drift underlies the whole of Chickasaw county. It has been almost completely covered by the later drift of the Iowan stage, but in the rain-cut gullies by the roadsides it is revealed at many widely separated localities. It is shown in scores of well sections, and the new work on the Great Western railway has led to the making of many cuts in which the Kansan appears. The new railway cuts southeast of New Hampton all show the relation of the blue Kansan till to the overlying yellow Iowan. In one of the cuts about two miles from New Hampton the stratified sands and gravels of the Buchanan substage lie between the Iowan and the Kansan. In some places the yellow Iowan till rests on undisturbed rusty gravels, and the line of separation is sharply defined; in other places the gravel has been worked up into the Iowan, in which case it is not easy to recognize the exact limits of the two formations. In general the unweathered Kansan is blue in color. It is also quite calcareous. There are many limestone pebbles embedded in the till, but greenstone fragments are more common. There are places, however, in the fresh railway cuts where the Kansan is almost black owing to the presence of a large amount of organic matter. Splintered fragments of branches and trunks of trees are conspicuous in most fresh sections, the remains of forests that occupied the state during the Aftonian interglacial interval, and were overwhelmed, broken, rolled, crushed and worked up into the subglacial till by the advancing glaciers of the Kansan stage. The exposed surface of the Kansan was weathered, leached, oxidized and reddened during the intervals between the withdrawal of the Kansan ice and

the advent of the Iowan. The roadside cuts show a number of places where the material of this leached and reddened ferretto zone has been worked into the Iowan till in such a way as to make the drawing of a sharp line of division impossible. The fresh, unmixed Iowan is quite calcareous, the Kansan ferretto is completely leached, the mixture of ferretto and Iowan responds feebly to the acid test.

While the Kansan drift was exposed to meteorologic agencies in the intervals between the close of the Kansan stage and the beginning of the Iowan, the surface was at times washed and beaten by rains and at other times was affected by winds in such a way as to remove quite an amount of the fine surface clay, leaving the contained pebbles and cobble stones as a sheet of gravel of varying thickness, conforming to all the inequalities of the eroded surface. This fact is discussed in the reports on Page. Howard and Tama counties. West of Devon in Chickasaw county the Iowa drift is thin. The old surface of the Kansan was not greatly disturbed by the action of the Iowan glaciers. The weathered ferretto zone of the older drift and the more or less perfect sheet of residual or concentrated gravels which covered the old pre-Iowan surface, are shown in the roadway, or in the deeper trenches by the side of the road, between Devon and North Washington.

Buchanan Gravels.—The great sheets and trains of gravel which were deposited as outwash at the time the Kansan ice was melting and gradually withdrawing from this part of Iowa, are very generally distributed. Like the surface of the exposed till, these deposits suffered from the effects of weathering during the very long intervals preceding the coming of the Iowa glaciers and the distribution of the Iowan till. The gravels are red and rusty, and all feldspar-bearing fragments of the transported rocks are rotted, decayed, disintegrated. As in Howard, Buchanan and other counties in northeastern Iowa, there are here two phases of the gravels, the upland phase and the valley phase. In the upland phase, which occurs on the higher areas, the beds are quite heterogenous in that they are composed of fine sand, pebbles, cobbles, and small bowlders ranging up to a foot in diameter. The valley phase is made up mostly of small polished quartz pebbles,

with little or no sand, and without the larger cobbles and bowlders. The mode of origin and deposition of the two types of gravel deposits is discussed in the report on Howard county.

A number of deposits of very typical, ferruginous, upland gravels occur in and around New Hampton. The foundation for the extension of the German Catholic church was excavated in such gravels. A very characteristic bed is seen at the creamery, one-fourth of a mile south of the Great Western railway station. The gravels are very deeply stained with iron rust, the iron constituents being completely oxidized. Some parts of the beds are wholly or partially cemented into a conglomerate by the re-deposition of the ferric oxide, and there are many hollow clay ironstones, the result of secondary concretionary processes. There are the usual decayed granites and other feldspathic rocks ready to crumble to minute fragments when removed from their surroundings, and there are also some hard, undecayed cobblestones which retain the glacial striæ. The bed was cut through in grading for the railway, and a section ten feet in thickness is exposed. Less than one-half mile farther south the railway has cut through another and more extensive bed of the same oxidized gravels in which are found all the charactistics of the upland phase. At this point the deposit forms an esker-like ridge, and east of the railroad there is a very large pit from which material has been taken and used in the improvement of the adjacent streets and roads. It is almost universally the case throughout northeastern Iowa that the lower part of deposits of upland gravels is made up of cross-bedded sands, while the coarser materials—the pebbles, cobbles and bowlders—are found only in the upper part of the section. This feature is very strikingly illustrated in the pit last mentioned. There is another large gravel pit at New Hampton two or three hundred yards west of the railway and south of the creamery. There is not the usual amount of coarse material in the upper part of this exposure; erosion may have carried it away; the excessive staining of the sand in the pit would indicate that such material had once been present in its ordinary position, for pure quartz sand could not furnish anything which, by oxidation, would give rise to ferruginous stains. At this point there is no Iowan drift overlying the deposit.

Two miles southeast of New Hampton there are some new cuts which show a comparatively thin sheet of Buchanan gravels lying between beds of blue Kansan, and yellow Iowan drift. At one point the Iowan till arches over a low, narrow ridge of the gravels. Farther on, the Buchanan deposit becomes thicker, and the bottom of the cut, occupied by the sandy phase of the formation, is above the surface of the Kansan drift.

It is not necessary, nor would it be profitable, to mention all the observed exposures of the upland gravels. From descriptions already given any one interested will be able to recognize these

FIG. 37. Exposure of the upland phase of the Buchanan gravels at the north end of Brasher street, Nashua.

beds at sight. For the purpose merely of indicating their general distribution, reference may be made to a typical section in a road cut, on the west side of the southwest ¼ of the southwest ¼ of section 3, Fredericksburg township, and to another near the opposite corner of the county, in the southeast ¼ of the southeast ¼ of section 21, in the northern part of Deerfield township,

within less than a mile of the Howard county line. Another excellent example occurs in a cut made for the wagon road through a high ridge near the southeast corner of the northeast ¼ of section 9, Chickasaw township. This is probably the thickest deposit of the gravels found in the county. Near the bottom of the hill there are a number of small springs and seeps, presumably at the line of contact of the gravels with the underlying Kansan clay. On the upland one-half mile east of Chickasaw there is a pit deserving notice for the reason that from it has been taken the material for making one of the best pieces of road in the county, that between Ionia and Chickasaw. An exposure of the upland type of gravels is seen in an unusual position at the north end of Brasher street in the city of Nashua (Fig. 27). The bed occurs only a few feet above the level of the Cedar river, and yet it shows none of the characteristics of the valley phase of these deposits.

The valley gravels are so universally distributed along all streams that it seems scarcely necessary to do more in discussing their distribution than simply to mention the fact. There are extensive deposits about Lawler. Farther up Crane creek the valley gravels take the form of fairly well defined terraces, as near Jerico in Jacksonville township. Along the Little Cedar from above Bassett to Bradford there is an almost continuous sheet of gravel covering the bottom of the valley. The broad bottom lands through which the converging branches of the Wapsipinicon flow in Dayton township, are underlain with gravel which affords perfect underdrainage to what would otherwise be wet and swampy land. It will be sufficient to say that every stream course of any consequence has its valley trains, and that no part of the county is far removed from an abundance of the best possible materials for the improvement of the country roads.

IOWAN STAGE.

Iowan Drift.—With the exception of some sandy hills along the Little Cedar river, west and southwest of Chickasaw, the Iowan drift is spread as a practically continuous mantle over the entire county. In many places this mantle is very thin, and in no place is it known to attain a very great thickness. The yellow cal-

careous clay of the Iowan is readily distinguished from the blue clay of the fresh, unweathered Kansan, and it is not likely to be confused with the red or brown weathered and oxidized zone of the older till. For facts bearing on questions of the relative age of the two deposits, see the report on Howard county. The Iowan drift is not so pebbly as the Kansan. Its transported rocks take the form of large bowlders, very much larger on an average than anything appearing in the Kansan. Furthermore, these bowlders are coarse granites of types altogether unknown in the older drift. Chickasaw county has been favored with an unusual number of

FIG. 38. Typical field of Iowan bowlders in the southwest quarter of section 18, Dresden township.

these erratic masses of granite (Fig. 38). It is doubtful whether any other county in Iowa is so well supplied. The value and amount of the high grade building stone which the Iowan glaciers carried from the north and deposited in this county are well nigh incalculable. There is an unusual area, small in size, about a mile and a half south of Bassett, in the southeast $\frac{1}{4}$ of section 17, Chickasaw township, where the surface is sprinkled with bowlders a foot or two in diameter, in a way resembling some portions of New England or New York (Fig. 39). But in general the rocks transported by the Iowan ice were brought in large masses, ten, fifteen or twenty feet in diameter. While in the aggregate, there-

fore, the mass is very great, almost beyond computation, the individual bowlders are rarely so numerous as seriously to encumber the surface. The largest of the many large bowlders seen in the

FIG. 39. Field showing an unusual number of small bowlders, in the southeast quarter of section 17, Chickasaw township.

county is that known as Saint Peter, located in the southwest 1/4 of section 3, near the center of Washington township. The view (Fig. 40) shows that great mass of granite as it was seen from a distance rising out of a tall and rank growth of oats. Saint Peter is fully twenty feet in height and more than eighty feet in circumference.

A large proportion of the Iowan bowlders lie on or near the surface as shown in figures, 32, 38, 39 and 40. This fact has led some prominent geologists to the hasty and untenable conclusion that they were transported on top of the ice as part of an accumulation of superglacial drift. It must, however, be evident to any one who thinks seriously about the matter that a continental ice sheet, like the Iowan, would be, like the ice cap of Greenland, wholly free from superficial detritus. Valley glaciers, like those

of the Alps, may become loaded with superficial material; and a piedmont glacier, like the Malaspina, made up of confluent mountain glaciers carrying medial moraines, might gather sufficient detritus on its surface to support a vigorously growing forest; but the possibility of any considerable amount of superficial drift on a continental glacier is too small to be seriously considered. That the bowlders of the Iowan drift were not super-

FIG. 40. Saint Peter, the largest bowlder in Chickasaw county, as seen from a distance rising out of a heavy growth of small grain, southwest quarter of section 3, Washington township.

glacial is abundantly attested by the fact that a very large proportion of them are planed and scored on one or more sides as shown in figure 41. Some of the very largest and most prominent of them have been broken up into blocks for building stone, and in every case the lower side has been found to be planed and worn by being dragged along underneath the ice. The Iowan bowlders are now on the surface for the reason, largely, that the Iowan glaciers carried a comparatively small amount of clay and other fine detrital material, and therefore the thickness of the Iowan drift sheet is not sufficient to conceal the great blocks of granite which were embedded in the lower surface of the ice.

FIG. 41. Glacial planing on an Iowan bowlder, a common feature of Iowan bowlders, and one showing they were not superglacial.

Data bearing on the thickness of the Pleistocene deposits will be given below in connection with the discussion of wells and water supplies.

Soils.

The soils of our territory show but little variety. Over most of the county the soil is a rich, deep, black loam developed on the Iowan drift. Some portions of the Iowan surface is not well drained and in certain seasons the soil is wet and heavy, but such areas are admirably adapted to the growth of some kinds of meadow grasses. There is very little of the county, however, that cannot be cultivated successfully in years of normal rainfall. The warm, black, fertile loam developed on the Iowan till, and very much the same wherever this drift is spread, is one of the most desirable, the most productive, the most inexhaustible of the soil types found in our great state.

In the broad sags which serve throughout most of the county for river valleys, extensive sheets of the valley phase of Buchanan gravels are present as a subsoil and afford perfect underdrainage to large areas which would otherwise be too wet for cultivation. On the hills about Nashua the soil is thin, the Devonian limestones coming near the surface. There is a small area of sandy

soil on the erosional hills west of the Little Cedar river, in sections 20 and 21, Chickasaw township. On the whole there is no part of the state more favored in the matter of soils than Chickasaw county.

ECONOMIC PRODUCTS.

Apart from the splendid soils of the county there are no geological deposits capable of supporting extensive industries. The quarries furnishing building stone have been individually described in the discussion of the Devonian. The most important quarries are those in Chickasaw and Bradford townships, for these are most favorably located with reference to markets; but probably the best grade of limestone occurring in the county is that seen near the center of section 25, in the southeast corner of Utica township. The old Bishop quarry (Fig. 36) might be made to yield a good quality of flagging stone. The immense amount of granite in the surface bowlders of the county constitute supplies of building material, ready to hand, which will be appreciated and utilized more and more as there is increased demand for substantial structures of every kind. The larger bowlders, as veritable granite quarries, will be systematically attacked with the best modern quarrying tools and broken into properly shaped blocks for bridge piers and heavy foundations.

Mr. Marion E. Ackley operates lime kilns at Chickasaw and supplies the local market with a product of excellent quality. It is the beds immediately below the Acervularia and stromatoporoid horizon that are used in lime burning. Lime was formerly made from the same beds at the old Bishop quarry, about a mile north of Chickasaw. Another lime kiln, which, however, has not been used for some years, is located in the southeast ¼ of section 20, Bradford township.

There is no limit to the amount of drift clays occurring in Chickasaw county, but clays suitable for the manufacture of brick and tile are not common. The objectionable feature in the drift clays is the great number of pebbles which are universally present. The blue Kansan till contains numerous limestone fragments which, even if the other pebbles could be disposed of, would effectually bar its use for the manufacture of clay products. The

Iowan clay is less objectionable than the Kansan on account of its practical freedom from pebbles of limestone. The only brick yard seen in the county is that operated by Mr. Cotant about three-fourths of a mile west of New Hampton. The clay used is the upper three feet of the Iowan drift, most of it the fine black surface loam or soil. The raw product is dried partly in the sun, partly on pallets under cover. The burning is done in small clamp kilns, with a capacity of 100,000 for each kiln. The plant includes a two horse-power, Iron Quaker machine of 20,000 daily capacity.

In the matter of road materials, the limestones may properly be counted among the available deposits; but the Buchanan gravels, both in their upland and valley phases, constitute by far the most important resources of the county in this direction. The siliceous pebbles mixed with a small amount of sand, just as they occur in most of the native beds, make an ideal road dressing. The material is cheap and, by reason of the wide distribution already described, it is everywhere at hand. The fine piece of road between Ionia and Chickasaw, and that leading south from New Hampton to Williamston, are impressive object lessons on the subject of what may be accomplished in the way of road improvement by a small amount of effort intelligently applied.

There are a number of beds of a fairly good grade of peat in various parts of the county. One of these is traversed by the new line of the Great Western railway near the southwest corner of section 17, New Hampton township. The peculiar prominent boggy elevations, known as "mound springs," which are seen on many of the low slopes of Iowan drift, furnishing water which may be piped down to drier ground at lower levels, are all accompanied by accumulations of peat of greater or less extent. A small but typical mound spring, with its attendant bed of peat, occurs in the southwest 1/4 of the southwest 1/4 of section 33 within a few yards of the south line of Deerfield township. The largest amount of peaty material in one place, was seen in a bench which rises above the level of the valley gravels in the northeast 1/4 of the northeast 1/4 of section 32, Chickasaw township. Peat is probably of no value at present, but as fuel becomes scarcer and more

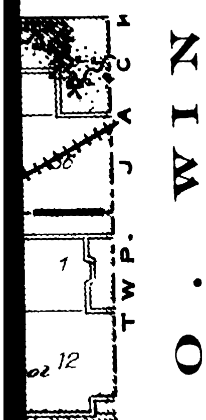
expensive, it may be profitable to briquette and dry the peat from some of the larger beds, and place it on the market.

Some small beds of limonite or bog iron-ore are found at a number of points in the county. None were seen of sufficient extent to justify their exploitation on a commercial scale. Probably the best known is that which occurs in the northeast 1/4 of section 24, Dayton township.

Water Supplies.

Chickasaw county is well supplied with an abundance of pure, wholesome water. No area of similar size is better provided with streams, and a proportionately large part of the population depend on stream waters as a supply for farm stock. There are not many springs in the county compared with some other regions of our state, but well water of good quality is readily found on every farm. Most of the wells end in the drift, water being found either in seams in the glacial clays or in streaks of sand and gravel interbedded with the clays. In the broad stream valleys water is usually reached at depths ranging from twenty to thirty feet, in the beds of gravel belonging to the Buchanan substage. In a few instances wells penetrate the underlying limestones.

The farm wells about New Hampton are reported to end in a bed of water-bearing sand which lies immediately on top of the limestones, and the depth of the wells ranges from 125 to 160 feet. Eight or ten miles north of New Hampton, drillers report that wells go down 200 feet without striking rock. A depth of 200 feet is not infrequently reached in Dayton and Fredericksburg townships without penetrating the whole thickness of the drift. The town well of Lawler, in the valley of Crane creek, goes down through Buchanan gravel and Kansan clay to a depth of 135 feet. It is 137 feet deep and is reported to go into the rock only a foot or two. Wells on higher ground near Lawler show a thickness of 165 feet for the Pleistocene deposits, and go some distance below the level of the stream in the adjacent valley before encountering rock. In a well near Jerico the limestone was reached at a depth of 221 feet. The railway well at Ionia is 145 feet deep and ends in what is reported as "quicksand." The boring of deep farm wells has furnished reliable data concerning the surprising thick-



CHICKASAW

COUNTY

IOWA.

BY

ness of the great mantle of drift which overspreads nearly the entire county and effectually conceals the underlying rocks.

Shallow wells drawing supplies of water from the great gravel trains of the Buchanan age, are found in all the stream valleys. At Lawler, for example, water is obtained on any of the residence lots by simply driving points into the gravel to depths of from fourteen to sixteen feet. In the vicinity of Little Turkey post-office driven wells need go only twenty-five feet into the gravel beds to get unfailing supplies. In all the other stream valleys the situation is much the same.

At New Hampton the city well has a depth of 235 feet. The mantle of drift is 135 feet in thickness; the boring went 100 feet into the limestones. The well is ten inches in diameter; the water rises within thirty feet of the surface; the supply is ample to meet all demands so far made upon it. In the western part of the county some of the farm wells penetrate rock to greater or less distances.

Remains of the Aftonian forests, in the form of splintered fragments of wood worked up into the blue Kansan clay, are found in nearly all wells bored into the drift. Well drillers report that it is not unusual to strike a flow of gas at depths ranging from twenty to forty feet. No decisive tests relative to the quality of the gas have been made, but it is stated that at Bassett a lighted lantern was extinguished when let down into a well from which gas was escaping. It is quite probable that all the gas encountered in boring wells in the glacial deposits of this region consists largely or wholly of carbon dioxide.

Water Powers.

Considering the number of streams, there are not many water powers developed in the county. The water power on the Cedar at Nashua, and those at Chickasaw and Greenwood Mills on the Little Cedar are the most important.

SUMMARY.

Chickasaw county presented few features of interest to the older geologists. It was simply a great prairie plain traversed by numerous clear streams. The soils are exceptionally deep and

exceptionally fertile; but the very depth and the universal distribution of the mantle of loose materials have effectually concealed the quarry stones and other geological resources. Agriculture is, and must always remain, the most important industry of this county. There is building stone enough for all local needs in the few limestone quarries and in the universally distributed granite bowlders. There is some good lime burning rock available, and road materials, in the form of extensive beds of Buchanan gravels, are everywhere abundant. If any one regrets the absence of coal and other mineral products, let him remember the wealth producing qualities of the soils, which no right thinking man would exchange for the conditions favorable to mining; let him remember that the farms of Iowa are worth more than all the gold and silver mines of America.

GEOLOGY OF MITCHELL COUNTY.

BY

SAMUEL CALVIN.

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CONTENTS.

COUNTY.

INTRODUCTION.

GEOLOGICAL, TOPOGRAPHICAL AND GEOGRAPHICAL RELATIONS AREA.

Mitchell county is bounded by areas on which geological reports have already been made. The geology of Howard is published in the present volume, that on Worth county appeared in volume X, and in volume VII the geology of Cerro Gordo county is discussed. From what is known of the geological structure of the counties adjoining Mitchell on the east and west, it might readily be inferred that, so far as relates to the stratigraphy of the indurated rocks, our territory lies wholly within the area occupied by formations belonging to the Devonian; and in its relations to the mantle of loose, soil-making materials, it is included in the area of the Iowan drift. Mitchell county is not traversed by the margin of any important geological formation, though in the drift series there are some interesting and significant islands of loess-covered Kansan which merge with rather indefinite limitations into the Iowan plain. These islands are parts of a series of small, loess-covered patches—surrounded by Iowan drift and separated by many miles of intervening Iowan plain from typical regions of loess—which are known to occur along the valley of the Cedar river from Mitchell county to beyond Cedar Rapids in Linn.

The region to be discussed in the present chapter is related in an interesting way to one of the larger topographic features of

the state, which affects a number of the adjacent counties. It is possible that this topography may have had something to do with the genesis of the anomalous loess islands noted above. In the report on Chickasaw county reference is made to the fact, pointed out by McGee in 1891, that the water courses of a part of northeastern Iowa, instead of following the general inclination of the surface, take a direction nearly at right angles to the predominant slope. Between the high divide on which Bonair, Cresco, Ridgeway and Calmar are located, and the Cedar river, the inclination of the surface is greatest toward the southwest, and yet all the streams of the intervening area are flowing toward the southeast. Osage, located on the Iowan plain ninety feet above the level of the Cedar river, is about 140 feet lower than Cresco. A line drawn between the two points would cross the drainage courses nearly at right angles. Along a line practically parallel to that just mentioned we get the following altitudes: Calmar 1263, New Hampton 1169, Charles City 1024. Farther south a similar line gives: Donnan 1151, Sumner 1060, Waverly 948. A nearly parallel line still farther south shows the following significant series of altitudes: Arlington 1113, Oelwein 1049, Fairbank 1000, Dunkerton 945, Dewar 889, Waterloo 841. The unusual behavior of the streams northeast of the Cedar is more strikingly illustrated when other facts are taken into consideration. For example, Devon in Chickasaw county, on the summit of a high divide, has an altitude of 1194 feet. A line drawn from Devon to Oelwein is approximately parallel to the drainage courses, the distance is thirty-nine miles, and the difference in elevation between the two points is 145 feet. In the direction of the drainage the surface has an average slope per mile of less than four feet. On the other hand, from Oelwein to Waterloo, along a line at right angles to the courses of the streams, the distance is twenty-six miles, the difference in elevation is 208 feet, the average gradient in this direction is eight feet to the mile. Riceville and Independence are both located on the Wapsipinicon river, they are about seventy miles apart, the difference in elevation between the two is 308 feet, the average gradient per mile in a straight line is less than four and a half feet. A line from Calmar to Charles City does not lie quite in the direction of the greatest

slope, and yet the average fall per mile from one point to the other is more than six feet. Investigations sufficiently comprehensive to cover the entire area under discussion show that the streams are not following courses coincident with the greatest inclination of the surface.

That the Cedar river occupies the bottom of a broad trough extending from Winneshiek county on the east to Kossuth county on the west, will be apparent if, in connection with the facts already given, the following series of altitudes from Charles City westward be taken into consideration: Charles City 1024, Nora Springs 1064, Mason City 1132, Clear Lake 1241, Garner 1223, Britt 1235, Wesley 1258, Algona 1194. The one break in the gradual rise from Charles City to Wesley is due to the fact that Clear Lake is located in the irregular ridge which constitutes the marginal moraine of the Wisconsin drift lobe. Algona is located in the valley of the Des Moines river, the next important stream west of the Cedar; its elevation, however, is 170 feet greater than that of Charles City. West of the Cedar the southeastward flowing streams follow the direction of the general slope of the surface. Mitchell county lies in the bottom of this great Cedar river depression, and to this fact it probably owes some of its most striking geological characteristics.

In making inquiry concerning the cause of the peculiar behavior of the streams between the Cedar river and the Cresco-Calmar ridge, certain facts are worthy of consideration. During late Tertiary time Iowa stood low with reference to sea level; it was reduced to a peneplain, and the sluggish streams flowed in shallow channels upon a nearly level surface. It may be conceived, however, that the direction of the drainage courses was a consequence of original slopes. About the beginning of the Pleistocene, but before the advent of the first invading glaciers, the whole country was elevated. This was particularly true of northeastern Iowa, which was lifted through 600 or 700 feet. The movement, however, was not uniform, but was greatest near the Mississippi river, and least along the line where now flows the Cedar. In this way the old peneplain was tilted toward the southwest. The upward movement was slow. As it progressed the streams were quickened and energized, and corrasion kept

pace with the uplift. Among other lines of evidence the deeply intrenched meanders of the Upper Iowa, or Oneota river, in the western part of Allamakee county, attest the fact that the region is an elevated peneplain. During the slow process of elevation all the streams held to their original courses and deepened their channels without being diverted from them, notwithstanding the great change which took place in part of the area in the direction of the predominant slope.

It is true that the rock-cut channels of the anomalous streams discussed above, excavated as they were before the earliest ice invasion of the region, were choked with glacial detritus; and it is also true that the modern streams of this peculiar region flow in broad sags and shallow trenches in the surface of the drift. But after the withdrawal of each of the successive ice sheets which affected northeastern Iowa, the preglacial valleys still expressed themselves in depressions in the mantle of drift, sufficiently pronounced to determine the course of the subsequent streams. The great trains of Buchanan gravels, described in the reports on Howard and Chickasaw counties as occurring in all the valleys of this part of the state, show that the present water courses have been the principal lines of drainage at least since the time of the melting of the Kansan ice. Each valley was in fact a trough before even the Kansan drift was deposited. The courses of the post-glacial streams seem to have been determined by preglacial erosion.

In its geographical relations Mitchell belongs to the northern tier of counties in Iowa. Its northern boundary is the north line of the state. It has Howard county on the east, Floyd on the south, and Worth and Cerro Gordo on the west. It is traversed by the axis of the great Cedar river trough, a geographic and topographic feature of more than usual importance. Townships belonging to the four ranges, 15, 16, 17 and 18 west of the fifth principal meridian, are embraced between its eastern and western boundaries. From south to north, within the limits of the ranges named, the county includes the north half of township 97, and all of townships 98, 99 and 100. Township 100 is less than five miles in length from north to south; sections 1 to 6 are absent, and sections 7 to 12 are fractional. From the number of sections in-

cluded in the county the theoretical area would be 480 square miles, but owing to the fact that all the townships fall below the standard dimensions both in length and width, the actual area is less than the theoretical.

PREVIOUS GEOLOGICAL WORK.

Compared with other prairie counties in northeastern Iowa the number of rock exposures in Mitchell is unusually great, and in point of interest many of these exposures are rarely excelled in any part of the state. Notwithstanding all this, Mitchell county has heretofore been practically neglected by official geologists. The pioneer investigations of Owen, conducted in the valleys of the Cedar river and its tributaries, on the limestones and shales making up the geological unit which he calls the "*Formation of Cedar and Part of Lower Iowa River, Belonging to the Devonian Period,*" were evidently not extended as far north as the county we are considering. In the *Geological Survey of Wisconsin, Iowa and Minnesota*, page 80, speaking of the range, extent and bearings of the deposit under discussion, he says: "The formation ranges, with a northwesterly curve, up the valley of the Cedar river; forming a belt, averaging, at first, some twelve or fifteen miles only in width, but gradually enlarging, until, when in latitude 43°, it disappears under the drift of Northern Iowa, it attains a width of from thirty to thirty-five miles." The parallel of 43° passes through the southern part of Floyd county, four or five miles south of Charles City, and Owen seems to have taken it for granted that there are no natural outcrops of Devonian limestones north of that line. A personal examination of the region would have shown the conclusion to be not well founded.

Whitney, in Hall's Geology of Iowa, volume I, part I, makes brief reference to the drainage of Mitchell county on page 306, and on page 311 there are detailed sections of beds exposed near the old town of Newburg, not far from St. Ansgar. White's report on the Geology of Iowa, published in 1870, makes no reference to the county under discussion.

The topography of Mitchell county, its isolated loess deposits and its Iowan bowlders, are discussed with some fullness by McGee in his *Pleistocene History of Northeastern Iowa*, and in

the same memoir the detailed sections of an interesting series of wells in this county, are given on pages 515 and 516.

PHYSIOGRAPHY.

TOPOGRAPHY.

In general the surface of Mitchell county is a gently undulating plain, such as everywhere characterizes typical areas of the Iowan drift. In this county there are only a few streams of sufficient importance to produce any marked effect upon the topography, but the few there are flow in valleys of unusual depth when compared with other streams traversing the Iowan plain. Accordingly the characteristic features of the drift plain are found in broad, unbroken belts between the principal water courses. A typical bit of Iowan topography occurs northeast of the Wapsipinicon river; another belt, five to eight miles in width and ex-

FIG. 42. An Iowan bowlder two and a half miles northeast of Osage. This, the largest bowlder seen in Mitchell county, is surrounded by a typical phase of the Iowan drift plain. The level, unbroken surface extends to the horizon.

tending the whole length of the county, lies between the Wapsipinicon and the Little Cedar river; the most extensive belt of characteristic and unbroken Iowan is that which occupies the

area between the Little Cedar and the Cedar, while west of the Cedar there is a very typical portion of the Iowan drift plain, broken into subordinate parts by Rock creek and Deer creek. In the central portions of the Iowan belts, or anywhere outside the immediate influence of the deep stream valleys, there are areas, extending in all directions to the horizon, which are seemingly as level as a floor. (Fig. 42). Along the streams, however, there are narrow belts where the drift is thin, where large bowlders of Iowan types show that the Iowa ice did once occupy the surface, but where the amount of detritus left by the latest ice invasion was insufficient to develop the representative topography of the ideal Iowan plain. In such regions the surface is usually strongly

FIG. 43. Undulating surface in areas of thin Iowan drift near the streams. The view was taken in section 4, township 97, range 17.

undulating as shown in figure 43. A concrete illustration of an area of thin drift, with undulating surface and protruding knobs of rock, may be found northwest of Mitchell, in sections 1 and 12, township 98, range 18. A very marked example of a region of thin Iowan, through which the pre-Iowan erosional topography still expresses itself, is seen in sections 22, 23, 26 and 27, Newburg township, a short distance west of St. Ansgar. The same type of topography is illustrated over and over again on both

sides of the Cedar river, from one end of the county to the other. Similar areas occur along the Little Cedar and, to a less extent, along the Wapsipinicon.

Probably the most surprising feature of the topography of Mitchell county is the great depth of the trenches in which the principal rivers flow. The valley of the Cedar, especially, departs widely from the type of valley usually seen in regions of Iowan drift. There are really two types of Iowan valleys. One is illustrated by the course of the Wapsipinicon and its several branches, as well as by Crane creek and some other streams, in Howard and Chickasaw counties. Here the streams follow broad, shallow sags in the surface, due to the fact that preglacial trenches were only partly filled with glacial detritus. The old valley which Crane creek still follows at Lawler in Chickasaw county, is filled with drift to a depth of 135 feet, and yet the stream flows in a broad sag which was determined by preglacial rock erosion. The other type of Iowan valley is illustrated in the narrow, shallow trench which accommodates the Shell Rock river in Worth and Cerro Gordo counties. This simple trench, which is illustrated in figure 12, page 128, volume VII of the reports of the Iowa Geological

FIG. 44. Precipitous rocky cliffs along the valley of the Cedar river, showing preglacial characteristics. View north of the southeast corner of section 21, township 98, range 17, two miles west of Osage.

Survey, seems to be due wholly to post-Iowan erosion. The same type of stream valley is shown in figure 45 in this report. The valley of the Cedar river in Mitchell county is unlike either of these types. Its depth and width are due largely to preglacial erosion, and the preglacial characteristics persist. There has been no permanent filling of the valley with drift. In type, this water way is allied to the water ways of the Driftless Area. There are the original precipitous rocky cliffs (Figs. 44, 49 and 51) rising vertically from sixty to eighty feet, and the total depth below the level of the upland plain ranges from ninety to 120 feet. The sides of the Cedar river valley are cut by deep erosion trenches, recalling the topography of the Driftless Area, or areas of thin Kansan drift; and the tributaries, few and insignificant though they are, enter the main stream through rock cut troughs or gorges. The valley of the Little Cedar resembles that of the Cedar in a small way. The valley of the Wapsipinicon conforms more closely to the Iowan type. In sections 8, 16 and 17, township 97, range 17, Rock creek flows in a channel with precipitous limestone walls, while in section 12 of the next township west, it is flowing on the surface of the Iowan drift at about the level of

FIG. 45. Rock creek in the southwest quarter of the northeast quarter of section 12, township 97, range 18, showing the usual type of stream in the Iowan drift; the water flows in a shallow trench only a few feet below the level of the cultivated fields.

the cultivated fields (Fig. 45). Near its mouth the channel of Rock creek is preglacial; out on the plain beyond the influence of the deep valley of the Cedar river, the channel has all the characteristics of a young, post-Iowan stream.

Preglacial characteristics are best developed in that part of the Cedar river valley lying between section 1, township 98, range 18, northwest of Mitchell, and section 1, township 97, range 17, south of Osage. Here the valley is deeper, the cliffs of limestone higher, and the mantle of loose soil materials covering the underlying Devonian rocks thinner than anywhere else. Here, too, adjacent to the valley, are a number of high points and plateaus rising more or less conspicuously above the level of the Iowan plain. As in the case of similar highlands near the Iowan border, these prominent areas are free from Iowan drift and covered with loess. On the outer margins of these areas the loess blends without very definite borders into the Iowan plain; on the inner side the loess descends almost or quite to the level of the river. One of the larger loess-covered areas occurs between Osage and the river, being best developed southwest of the city, in sections 26, 27, 34 and 35, township 98, range 17. This area is large enough to afford a typical illustration of loess-Kansan topogra-

FIG. 46. Loess-Kansan topography in the southern part of the Osage-Mitchell loess island, in the northeast quarter of section 35, township 98, range 17.

phy (Fig. 46), such as occurs anywhere immediately outside of the Iowan margin. Another loess area characterized by the usual loess-Kansan, erosional topography, occurs on the west side of the river, west and northwest of Mitchell.

Why these loess islands and these unique preglacial features of a river valley, so strangely out of place in the midst of an Iowan plain? It may not be possible to give a satisfactory answer to these questions. It will be remembered, however, that the Cedar river occupies the bottom of a broad trough which affects the surface on a large scale. This great depression is nearly 250 feet in depth; it has Calmar in Winneshiek county on one margin and Wesley in Kossuth county on the other. The geographical position of the phenomena demanding explanation would suggest some possible causal relation between them and events taking place along the bottom of the Cedar river depression during the successive glacial invasions of northeastern Iowa. It is conceivable that the surface of the glaciers, particularly of the thin Iowan glaciers, dipped from both directions toward the bottom of this trough, much as the general land surface does today, but without the corrugations which determine the courses of the modern streams on the sides of the great depression. Under certain conditions of ice melting the waters resulting from surface ablation would be gathered together in a strong stream flowing along the bottom of the trough. Early in the process of melting the ice sheet was probably split in two along the axis of the depression, and the valley was swept clean of glacial detritus. The thin Iowan ice would be especially liable to be cut through by the action of the vigorous axial stream. The high loess-covered knobs and plateaus may never have been overflowed by the Iowan glaciers; in fact the more prominent of these certainly show no traces of Iowan drift. They received their mantle of loess in the same way that other extra-marginal areas were loess-covered at the time of culmination of the Iowan stage.

DRAINAGE.

Mitchell county is drained by three principal streams, the Cedar, the Little Cedar and the Wapsipinicon. Each of these rivers is almost entirely devoid of permanent tributaries so far

as this county is concerned. The larger water courses are bordered by broad belts of prairie land, the surface of which is drained by the flow of storm waters along shallow depressions that scarcely break the level monotony of the Iowan plain. Rock creek and Deer creek, west of the Cedar river, are the most important of the minor streams. A few sections are drained by Spring creek, which joins the Cedar from the northeast, near the south line of the county.

Altitudes.—The following short table from Gannett's Dictionary of Altitudes, showing the relation of a few of the more important points in the county to sea level, is not without significance. The first four places are located near the axis of the Cedar river trough, but are up on the Iowan plain, not in the river valley. Carpenter, on the level plain west of the Cedar, may be compared as to altitude with St. Ansgar; but more significant is the comparison which may be made of Riceville in the Wapsipinicon valley with Osage on the upland plain, ninety feet above the Cedar river.

	FEET.
Otranto	1,178
St. Ansgar	1,175
Osage	1,163
Orchard	1,090
Carpenter	1,198
Riceville	1,229

Between Otranto and Orchard, parallel to the axis of the valley, the fall is 4.5 feet to the mile; between Riceville and Osage, at right angles to the drainage, the average fall per mile is 4.7 feet.

STRATIGRAPHY.

General Discussion.

Mitchell county offers no great variety of geological formations. Only two systems are represented, the Devonian and the Pleistocene. In the Devonian but a single stage is recognized, the Cedar Valley stage of the Middle Devonian. There are natural exposures of two stages of the Pleistocene, the Kansan and the Iowan. In some well sections there are indications of the pre-

Kansan drift. Devonian limestones come to the surface along all the principal streams. In the Cedar river valley there are exposures at intervals from Orchard to Otranto. There are outcrops of Devonian near McIntire in the eastern part of the county and near Carpenter in the west. In the central part stone is quarried at numerous points near Brownville, Little Cedar and Staceyville. Notwithstanding the great number and wide distribution of the rock exposures, the aggregate thickness of the Devonian strata seen in the county does not exceed ninety feet. There are a number of vertical cliffs within a few miles of Osage —in sections 21, 27, 28 and 34, township 98, range 17—which individually show practically the whole succession of the Devonian beds seen in the entire county.

The larger stream valleys of the county are about parallel to the strike of the strata, and northeast of the Cedar river the slope of the surface conforms very closely to the general southerly and southwesterly dip. The same beds which are quarried at Orchard

FIG. 47. The Lewis lime quarry, in the southeast quarter of section 27, Osage township, one and one-half miles southwest of Osage.

are quarried near St. Ansgar; the quarrystone beds at McIntire are the same as those burned for lime southwest of Osage. Each exposure examined throughout the whole county proves to be in some measure, a repetition of every other. One striking feature of the geology of Mitchell county is the extraordinary development of the fine-grained, whitish, lithographic beds which mark a very definite and easily recognized horizon in Howard, Chickasaw, Cerro Gordo and other counties as far south as Johnson. Here the lithographic zone is much thicker than usual, the bedding is more regular (Figs. 47 and 48), and the texture of the

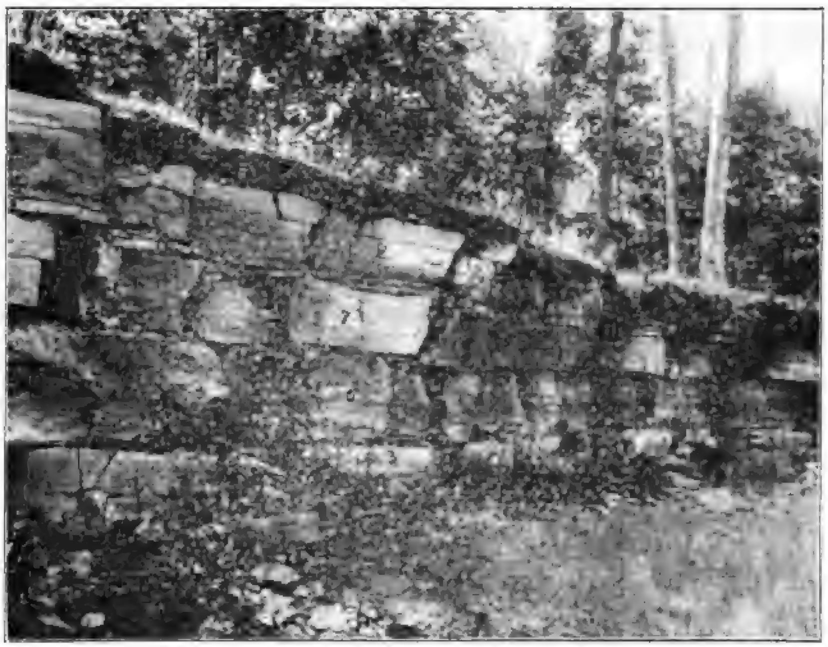


FIG 48. Lithographic beds in the Gable quarry in the northwest quarter of the southeast quarter of section 27, township 98, range 17.

stone is very much finer. The lithographic horizon is the highest represented in the county. The beds resist solution and weathering remarkably well, and they crop out in nearly all parts of the county on hill slopes, or even on level plains wherever the drift is thin. All the strata belonging to the horizon of the Salisbury quarry and other quarries about Vernon Springs and Cresco in

Howard county, are absent from Mitchell, or are represented only by beds of waste overlying the lithographic zone.

SYNOPTICAL TABLE.

The following table shows the taxonomic relations of the geological formations of Mitchell county:

GROUP.	SYSTEM.	SERIES.	STAGE.	SUB-STAGE.
Cenozoic.	Pleistocene.	Glacial.	Iowan.	Loess.
				Iowan till.
			Kansan.	Buchanan gravel
				Kansan till.
Paleozoic.	Devonian.	Middle Devonian	Cedar Valley	

Devonian System.

TYPICAL SECTIONS.

The Lewis Lime Quarry.—In the southeast ¼ of section 27 and the northeast ¼ of section 34, Osage township, there are many quarries and natural outcrops which together afford a very complete section of the upper part of the Devonian as it is developed in Mitchell county. A large quarry (Fig. 47) on the land of J. H. Brush, operated by George Lewis in the production of building stone and the manufacture of lime, gives the following standard section of the lithographic zone:

		FEET	IN.
10.	Dark brown residual clays with some granular, calcareous, residual material resembling fine sand, and many weathered chips of limestone	4	
9.	Firm, whitish, fine-grained ledge of concretionary lithographic limestone containing a number of obscure stromatoporoids.................		10
8.	Parting of shaly, fossiliferous limestone; fossils mostly in the form of comminuted brachiopod shells, among which some small Spirifers and Cyrtinas are recognizable.....................		3

	FEET.	IN.
7. Hard, fine-grained lithograpic limestone with lamination planes well defined in some places, less perfectly defined in others, and with a tendency to split up into individual layers of varying degrees of thickness	1	2
6. Marly shale		3
5. Heavy ledge of fine-grained lithographic stone dividing into two parts, the upper ten, the lower seventeen inches in thickness. The lower five inches is very fine and homogenous in texture and tends in places to separate as a distinct layer	2	3
4. Thin shaly parting		1
3. Ledge of fine-textured lithographic stone in three parts, eight, seventeen and a half, and three and a half inches respectively	2	4
2. Shaly parting		1
1. Coarser and less perfect lithographic stone in two parts eleven and nine inches thick	1	8

Beds 3, 5, 7 and 9 are fine-grained and light colored, break with conchoidal fracture, and would all be classed as lithographic limestone. It is the upper eight inches of No. 3 and the lower five or six inches of No. 5 that are fine enough and homogeneous enough to give promise of possessing commercial value as serviceable lithographic stone. All the beds are checked and jointed on an extensive scale, and this renders it difficult to obtain blocks of usable size for lithographic purposes. A few yards southeast of the quarry described, the beds lying below No. 1 are exposed so as to afford the following general section in which minor details are omitted:

	FEET.	IN.
6. Impure dolomitic limestone varying in texture, layers ranging in thickness from two to fourteen inches	8	
5. Heavy lithographic ledge, light gray in color, with fine texture, includes great numbers of minute, rhomboidal crystals of calcite	2	2
4. Calcareous shale		6
3. Argillaceous limestone decomposing rapidly by exposure to weather, upper four or five inches more resistant	2	
2. Series of irregular courses of grayish, magnesian limestone, varying laterally in color and thickness in the same layer		4

		FEET.	IN.
1.	Soft, yellow, earthy, regularly bedded magnesian limestone in five layers which are 5, 14, 8, 5 and 14 inches in thickness respectively, layers separated by shaly partings, total thickness exposed	4	6

In the immediate vicinity of the Lewis quarry there are many rock exposures in the steep bluffs along Sugar creek, and quarries have been operated at a number of points. Beyond the slight variations in individual layers which may always be expected, there is nothing in all the exposures essentially different from the several members of the two sections already described. For example, in some parts of the quarry of L. D. Green, located on the south side of the ravine followed by the wagon road in the northeast 1/4 of section 34, the equivalent of the upper part of No. 3 in the Lewis quarry divides along definite lamination planes into thinner portions varying from half an inch to two inches in thickness. The texture seems to be even finer and better adapted to high grade lithographic work than in the quarry first noted. Some of the other layers, notably the equivalent of No. 7, show a tendency to divide into thin laminæ.

It were scarcely possible or desirable to describe all the outcrops and artificial openings in this locality. The lithographic beds are quarried at an opening on the land of Dr. W. H. H. Gable in the northwest 1/4 of the southeast 1/4 of section 27, about half a mile northwest of the Lewis quarry. The layers worked embrace Nos. 3, 5, 7 and 9 (Fig. 48). There is no waste above No. 9, the stripping consisting of a very thin layer of humus. The remarkable durability of the fine-grained beds is well illustrated by the scarcely perceptible effects produced by weathering and solution on bed No. 9, notwithstanding its proximity to the surface. Checks and joints are more numerous here than at the Lewis lime quarry, due probably to greater exposure to alternations of temperature, but otherwise the ledges present no essential differences. Southwest of the Gable quarry there is a steep bluff facing the river and showing the succession of beds below the lithographic zone. A little more than one-fourth of a mile east of the Gable quarry, the underlying dolomitized beds have been quarried to some extent, in the south bank of Sugar creek.

A quarry worked for lime and building stone by Mr. Ritter is located near the east line of the southeast ¼ of section 27, north of the Osage road. The section includes all the beds seen in the Lewis quarry. The characteristics are those usual to the horizon of the lithographic stone. The ledges above No. 3 are in part split up into a number of thinner layers, as in the Green quarry. A short distance west of the city limits of Osage, near the center of section 26, there is a quarry showing the lithographic zone. The section is the same as at the Lewis quarry except that the lower part of No. 3 is very shaly, the upper, fine-grained part of 3 is 9½ inches thick, the upper part of No. 5 thins out to zero at one place and 7 and 9 are blended into a single layer. The lithographic stone is again exposed west of the bridge over Sugar creek, in the southeast ¼ of section 22, township 98, range 17. Some quarrying has been done on opposite sides of the road, both in section 22 and section 27. The layers of the Lewis quarry, excepting 8, 9 and 10, are present and show the usual characteristics. The limestone is here overlain by three feet of fine silt-like loess.

The Chandler Cliff Section.—There are some picturesque bluffs on the east side of the river, in the southeast ¼ of the southeast ¼ of section 21, directly west of Osage, which afford the following section:

		FEET.	IN.
26.	Residual clay in which thin, weathered slabs and flakes of limestone are embedded, part of mantle of waste	4	
25.	Coarse-grained, rough, weathered, magnesian limestone		6
24.	Firm, fine-grained, lithographic ledge, somewhat concretionary and containing imperfectly preserved stromatoporoids, the equivalent of 9 of Lewis quarry	1	
23.	Partly decayed and partly shaly layer, the equivalent of numbers 6 and 8 of the Lewis quarry. No. 7 has thinned out and is not represented in this section	1	
22.	Fine, light-colored, lithographic bed, equal to No. 5 of Lewis' quarry. The bed as usual shows two divisions which are separated by a peculiar suture-like joint due to the interlocking of small prominences from the apposed surfaces. This interlocking joint is seen in all the exposures of this vicinity between the two parts of No. 5. The interlocking denticles show stylolitic structure	2	

		FEET.	IN.
21	Shaly parting		1
20.	Lithographic limestone in three parts: No. 3 of the Lewis quarry; upper part as usual very fine-grained and homogeneous	2	6
19.	Shaly parting		2
18.	Fine-grained, lithographic stone equivalent to basal member of the Lewis quarry	1	
17.	Coarse dolomitic layer	1	
16.	Fine-grained, laminated layer	1	
15.	Coarse, granular dolomite in beds ranging from six inches to a foot in thickness	4	
14.	Shaly parting		6
13.	Bed with lithographic nodules embedded in granular matrix	1	2
12.	Heavy layer which is dolomitic below and partly lithographic above. The lithographic portion is joined to the coarser dolomite by a wavy and irregular line	1	2
11.	Shaly band, variable in thickness, averaging about		6
10.	Heavy layer of crystalline dolomite	1	6
9.	Shaly parting		2
8.	Thick layer of limestone, coarse and granular at the base, upper six inches partly lithographic	1	6
7.	Hard, light gray, lithographic stone	1	1
6	Shaly decayed limestone	1	
5.	Light gray, crystalline limestone, good building stone	1	2
4.	Evenly bedded, yellowish dolomite, good quality, quarried for building stone at many points in the county, layers ranging up to a foot or more in thickness, no fossils	9	
3.	Irregularly and indefinitely bedded dolomite, much checked and cut by joints, carries numerous casts of *Athyris vittata* and other species characteristic of the same horizon. This member will be referred to in subsequent parts of this report as the Athyris zone	12	
2.	Two heavy, irregular, non-laminated, dolomitic beds, containing many shapeless cavities lined with calcite	5	
1.	Magnesian limestone, partly dolomitic, in regular layers	15	

The coarse, heavy, structureless beds of number 2 are quite constant over an area of considerable extent, and they afford a good datum line on account of the ease with which they can be recognized in all the cliff exposures from above Mitchell to three

or four miles below Osage. Number 3 is also very persistent, the most characteristic fossil in all the sections along the Cedar river being *Athyris vittata.* Numbers 4 and 5 are the most important of the building stone beds in the county. They are quarried at Orchard near the southern boundary, and near St. Ansgar in the northwestern quarter. The upper part of number 12 and the whole of 13 appear to be the equivalent of the thick lithographic bed with calcite crystals, numbered 5 in the section below the level of the Lewis quarry. This seems to be a very variable member of this part of the Devonian section, for at the Frank Nickerson quarry, on the river bluff a little more than a mile and a half south of Osage, it is divided into three distinct parts with a thin band of coarse dolomite between the upper part and the one next below. The equivalents of the Lewis quarry beds are noted in giving the details of the several members from 18 to 24 inclusive. In this section there is more of the limestone overlying the lithographic beds than was seen at any other point in the county.

FIG 49. Cliff below the wagon bridge in the northeast quarter of section 28, township 98, range 17. There are folded and brecciated beds at the base of the cliff; the lithographic limestone appears at the top.

In the northwest ¼ of section 28, township 98, range 17, one-fourth of a mile below the electric power plant and two miles west of Osage, there is an interesting cliff (Fig. 49), which shows beds ranging down fifteen or twenty feet below No. 1 of the Chandler cliff section. These lower beds have been deformed and crushed on an extensive scale, the crushing having taken place before the overlying beds of the Chandler cliff were deposited. One of the larger and flatter of the arches into which the beds were thrown appears to the right of the middle of the view. The crushing and folding have been more energetic, or at least more effective, on each side of the arch. Immediately to the left the crushing seems to have been more perfect than elsewhere in this exposure, and the broken fragments of the original beds, ranging from a fraction of an inch to more than a foot in diameter, are now standing at every possible angle (Fig. 50). In some cases a certain amount of continuity may be traced from fragment to fragment of the same bed, the pieces showing very clearly that they are the constituent parts of a collapsed arch, but in general the displaced and

FIG. 50. Near view of the crush breccia at the base of the cliff shown in figure 49.

broken portions of the several beds are promiscuously jumbled together in perfect disorder. The matrix is composed of very finely comminuted fragments of the original beds mixed with finer, gray, granular, argillaceous limestone. It is probable that the entire matrix is detrital. Toward the right of the view there are several small arches, sharply curved and more or less broken. This section shows all the strata from the crushed zone up to the lithographic bed No. 7 of the Lewis quarry.

Near the northwest corner of section 1, and the northeast corner of 2, township 97, range 17, there are some fine precipitous rocky bluffs showing the equivalent of the brecciated zone at the base, overlain by the successive members of the Chandler cliff section. The lithographic layers, differing but slightly from the corresponding beds at the Lewis limekiln, have been quarried on the brow of the hill, on land belonging to Mr. Nickerson. The Wilkin brothers have a large quarry, or series of quarries, in section 1, at which point the beds equivalent to 5 and 7 of the Lewis section are more than usually laminated. The beds of the crushed zone at the bottom of the cliff, show rather gentle folding, the folds being broken and brecciated at only a few points, and these of limited extent. A rather majestic looking cliff on the south side of the river, near the center of section 34, township 98, range 17, repeats the details of the Chandler section; and another cliff south of the center of section 28, affords nothing but a repetition of the same details. At the last named point the crushed zone is concealed by talus. Another similar cliff belonging to the Chandler group, occurs on the south side of the river, south of the middle of section 21.

Rock Exposures Near Orchard.—The Devonian limestone lies within a few feet of the surface of the upland plain in and around Orchard. The Bartlett quarry in the eastern edge of the village is simply a pit sunk below the level of the plain. Only the upper lithographic beds are here exposed, and they contain the usual stromatoporoids seen in No. 9 of the Lewis quarry. A short distance above the railway bridge over Spring creek, there is a quarry in the low bluff of the stream, beginning at the level of the water. The horizon is that of the evenly bedded dolomite, No. 4 of the Chandler section. The quarry is capable of furnish-

ship 98, range 18, the road is cut through ledges of the lithographic zone. Between the Athyris bed at the quarries near the bridge south of St. Ansgar and the lithographic beds one mile farther south, the difference in level is thirty-five feet. The equivalents of 3, 5, 7 and 9 of the Lewis quarry are readily recognized. The stromatoporoids of No. 9 are better preserved than those of the corresponding bed near Osage and Orchard. They are also more numerous, and the individual colonies are larger; and yet they fall far short of the enormous development which the stromatoporoids of this bed attain near Nora Springs and Mason City. While the characteristics of the lithographic beds are probably more constant over wide areas than those of any other zone in northeastern Iowa, at this exposure, two and one-half miles south of St. Ansgar, the several layers vary in the most unexpected manner within a very short distance. At the north end of the exposure the beds are of the usual unaltered lithographic type; toward the south end, not more than thirty feet away, the section involving the very same beds is nearly all dolomite. In the dolomitized parts of No. 9 the stromatoporoids are represented by rough, spongiose masses from which the original structures of the fossils have been wholly or partially dissolved.

In the road one-fourth of a mile directly west of St. Ansgar, the Athyris bed, with its usual association of fossils, is well shown; and the quarry located above the bridge and west of the river, three-fourths of a mile southwest of the town, is worked in the dolomite which lies above the Athyris zone. There are exposures in the east bluff of the river north of the bridge at Newburg, which show the Athyris bed and the overlying dolomite. In the small gullies eroded in the sides of the bluff, blocks of lithographic stone occur with other waste material near the level of the upland, but no lithographic beds were here seen in place. The strata here dip to the north, and the Athyris beds disappear below the level of the water in the mill pond, near the center of section 14. It seems probable that it is these exposures east of Newburg that Whitney describes on page 311 of Hall's report on the Geology of Iowa. The Spirifer which Whitney mentions as resembling *Spirifer mucronatus* is doubtless the *Spirifer subvaricosus* of the Athyris zone, found near the southern end of the exposure.

lithographic beds of the Lewis quarry, is seen at the west end of the mill dam at Mitchell. At the level of the water below the dam there are two feet of beds belonging to the brecciated horizon. No. 1 of the Chandler section is represented by eleven feet of regularly bedded dolomite which is divided by a six inch band of shale about three and a half feet from the top. The coarse, unstratified bed with calcite-lined cavities, No. 2 at the Chandler cliff, presents the usual characteristics and the usual thickness. The soft yellowish limestone with casts of Athyris is reduced to five feet. This is followed, however, by five feet of harder dolomite in which fossils could not be detected, but which should doubtless be classed as part of the Athyris bed. Above this the evenly bedded quarry stone, No. 4 at Chandler's, has a thickness of fifteen feet, and this is overlain by three heavy ledges of hard dolomite which would furnish excellent material for bridge piers or for lime burning. Quite an amount of stone has been taken out here toward the top of the bluff at the horizon of No. 4. A number of other quarries have been operated within a mile of Mitchell. There is one, for example, west of the river in the northwest ¼ of section 8, and there are quarries on both sides of the river in the southwest ¼ of section 5. All make use of the evenly bedded stone belonging to the horizon of No. 4 at the Chandler cliff.

St. Ansgar Exposures.—Near the northeast corner of section 35, township 99, range 18, a mile and a half south of St. Ansgar, two quarries have been opened at points only a few rods apart. In both the stone is highly magnesian, in general dolomitic. The lower beds of the north quarry are rich in casts of brachiopods, *Athyris vittata* being the most common and the most characteristic. Casts of *Spirifer subvaricosus* are not uncommon, and in one of the layers *Atrypa reticularis* is plentiful. The fossils indicate at once the horizon of the Athyris bed at Chandler's cliff. In both of these quarries it is the evenly bedded dolomite, No. 4, above the Athyris horizon, that is worked. The south quarry is operated by C. H. Sherman of St. Ansgar, and is producing a durable stone, excellent for rough masonry. The range of the beds from two to thirty inches in thickness makes it possible to select stone suited to any desired purpose. One mile south of the quarries noted above, near the northeast corner of section 2, town-

ship 98, range 18, the road is cut through ledges of the lithographic zone. Between the Athyris bed at the quarries near the bridge south of St. Ansgar and the lithographic beds one mile farther south, the difference in level is thirty-five feet. The equivalents of 3, 5, 7 and 9 of the Lewis quarry are readily recognized. The stromatoporoids of No. 9 are better preserved than those of the corresponding bed near Osage and Orchard. They are also more numerous, and the individual colonies are larger; and yet they fall far short of the enormous development which the stromatoporoids of this bed attain near Nora Springs and Mason City. While the characteristics of the lithographic beds are probably more constant over wide areas than those of any other zone in northeastern Iowa, at this exposure, two and one-half miles south of St. Ansgar, the several layers vary in the most unexpected manner within a very short distance. At the north end of the exposure the beds are of the usual unaltered lithographic type; toward the south end, not more than thirty feet away, the section involving the very same beds is nearly all dolomite. In the dolomitized parts of No. 9 the stromatoporoids are represented by rough, spongiose masses from which the original structures of the fossils have been wholly or partially dissolved.

In the road one-fourth of a mile directly west of St. Ansgar, the Athyris bed, with its usual association of fossils, is well shown; and the quarry located above the bridge and west of the river, three-fourths of a mile southwest of the town, is worked in the dolomite which lies above the Athyris zone. There are exposures in the east bluff of the river north of the bridge at Newburg, which show the Athyris bed and the overlying dolomite. In the small gullies eroded in the sides of the bluff, blocks of lithographic stone occur with other waste material near the level of the upland, but no lithographic beds were here seen in place. The strata here dip to the north, and the Athyris beds disappear below the level of the water in the mill pond, near the center of section 14. It seems probable that it is these exposures east of Newburg that Whitney describes on page 311 of Hall's report on the Geology of Iowa. The Spirifer which Whitney mentions as resembling *Spirifer mucronatus* is doubtless the *Spirifer subvaricosus* of the Athyris zone, found near the southern end of the exposure.

The surface markings of the two Spirifers are very much alike.

There are a number of stony hills with rock near the surface, in sections 12 and 13, township 99, range 18, from one to two miles north of St. Ansgar. In section 13 the railway follows the base of a stony escarpment which sets off the upland prairie from the Cedar river valley. One-eighth of a mile north of the bridge over Turtle creek in section 13, there is an exposure that has been quarried. The rock is evenly bedded and seems to be the equivalent of the quarry stone south of St. Ansgar, the equivalent of No. 4 of the Chandler cliff section.

There are some good exposures in the vertical bluffs on the west side of the river, in the northeast ¼ of section 3, township 99, range 18. Stone has been quarried at a number of points. Quarrying begins at the top of a talus slope, fifteen feet above the base of the cliff. The breast of the quarries includes twelve feet of heavy, non-laminated, vesicular dolomite which is overlain by four feet of laminated beds which may be split into thinner slabs as desired. The upper part of the Athyris zone is here included in the workable quarry beds, the layers of this zone being much firmer, and the bedding more regular, than is the case farther south. The fossils are represented by cavities rather than casts. Three-fourths of a mile below, and on the opposite side of the stream, is the Hanson quarry which works only the laminated beds of the section described above, together with the uppermost portion of the heavier, vesicular beds beneath.

Otranto Exposures.—Only the lower members of the sections around Osage are represented near Otranto. The highest beds exposed in this region belong to the Athyris horizon, and these differ somewhat in texture, color and fossil contents from the corresponding beds farther down the river. In the southeast ¼ of the southwest ¼ of section 28, township 100, range 18, there are outcrops of the Athyris zone in the form of soft, granular, cream-colored limestone which breaks up into irregular, shapeless pieces on weathering. The beds are quite fossiliferous. *Atrypa reticularis* is the most common, but the typical *Athyris vittata* is not rare. Directly north of the last point, in the southeast ¼ of the northwest ¼ of the same section, there is a quarry from which a considerable amount of stone has been taken out. The rock is

soft, yellow, coarse-grained, very vesicular and rich in casts of *Atrypa reticularis*. There are also casts of *Athyris vittata*, and *Dielasma iowensis*, a species occurring in some places very abundantly at this horizon, appears more rarely. There runs through this quarry a band of dark shaly carbonaceous material which has been mistaken by the quarrymen and others for indications of coal. There is an opening near the mill at Otranto showing the same vesicular, yellow limestone seen at the quarry just described. The same stone appears in the bluff a short distance above the Otranto bridge. It crops out at a number of places along Otter creek northeast of Otranto, a good exposure occurring a short distance north of the southeast corner of section 15, Otranto township.

Exposures West of Cedar River on Rock Creek and Deer Creek.—In the northwest ¼ of the northeast ¼ of section 17, township 97, range 17, a short distance above the bridge over Rock creek, there is a small opening which shows bed No. 3 of the Lewis quarry section, and all the overlying beds up to the mantle of waste and broken stone above No. 9. In all this region the limestone lies very near the surface; it is exposed in natural sections in the low banks of the creek; quarries might be opened at a score of points if the demand for building material justified the labor and expense.

The Gopelrud quarry is located in the northeast ¼ of the northeast ¼ of section 22, township 98, range 18. It is opened along the south bank of Rock creek for a distance of 200 yards. The individual beds vary within short distances, but near the middle of the opening there are at the bottom a number of more or less perfectly lithographic layers ranging from an inch to ten inches and aggregating four feet in thickness. This is followed by a heavy, stromatoporoid bearing bed, two and a half feet thick, in which occur a small branching Favosites, an Alveolites with small tubes resembling *A. rockfordensis*, and some colonies of Diphyphyllum. Above the stromatoporoid bed are two to five feet of granular, decayed dolomite which furnished casts of a Cyrtina. The limestones exposed at this point embrace the lithographic zone, but they show quite an amount of variation in the several members of the section when compared with the standard section

at the Lewis quarry. The stromatoporoid bed, the equivalent of No. 9, is much thicker than it is near Osage, and it has assumed more of the characteristics of this bed as it is developed near Mason City and Nora Springs. The variations in the individual beds recall the interesting section in the roadside two and a half miles south of St. Ansgar. A bed that is lithographic in one place may be changed to dolomite within a few yards; what is a single layer in one part of the quarry may be divided into two or more distinct layers in another part.

Near the middle of the north line of section 8, Newburg township, there is an interesting section in the south bank of Deer

FIG. 52. Folded beds of the brecciated zone in the bank of Deer creek, near the middle of the north line of section 8, Newburg township.

creek (Fig. 52), which affords the best example of complex folding seen in the county. The stone is an earthy dolomite, and is destitute of fossils as far as could be observed. The cliff is from fifteen to eighteen feet in height, and all the beds have been thrown into a succession of undulating folds as shown in the

figure. Although the beds contain no fossils, and no recognized members of the Devonian section of the county are present to indicate their stratigraphic relations, the outcrop may be referred without much hesitation to the horizon of the crushed and brecciated zone in the lower part of some of the sections near Osage. The folds resemble those seen at the base of the cliff below the Wilkin Brothers' quarry. It is only at the brecciated horizon that any indications of crushing and brecciation have been observed in Mitchell county.

Exposures on the Little Cedar.—There are several quarries and exposures within a radius of one or two miles of Brownville. Rock crops out in a section six feet in thickness, in the bank of the river below the mill, but it is all so much weathered that its characters are obscured. A quarry on the Mosher farm, about two miles up the stream, furnished a good grade of heavy stone for the abutments of the bridge at Brownville. The Moss quarry on Beaver creek, in the southeast ¼ of section 30, Jenkins township, is worked in evenly bedded magnesian, or dolomitic limestone. It is opened for a distance of fifteen or twenty rods along the bank of the creek, and the individual beds vary considerably when traced from one part of the quarry to another. Some bluish, non-dolomitic pieces lying loose in the bottom of the quarry show traces of Atrypa and Spirifer, and these were the only fossils observed in the entire outcrop. There are exposures of magnesian limestone below Brownville, as far as the southeast ¼ of the southwest ¼ of section 32 in the southwestern part of Douglas township. Above Brownville the outcrops are more numerous and more important. Stone crops out along the stream for some distance above and below the town of Little Cedar. In the northeast ¼ of the southeast ¼ of section 22, Liberty township, there is a quarry furnishing good range stone from what is the equivalent of No. 4 at the Chandler cliff, the horizon from which comes most of the quarry stone of Mitchell county. Along the north line of the same section the lithographic beds are exposed at the level of the upland prairie. The rock section here evidently repeats the sections near Osage. In the west bank of the river, one-half mile southeast of Stacyville, a quarry has been opened in dolomitic limestone of fairly good quality. The layers range from three to

fourteen inches in thickness. The quarry is overlain by a large amount of decayed stone, particularly on the west side; farther east the stripping includes a fairly well developed bed of rusty Buchanan gravel of late Kansan age, and above this there is a loess-like deposit overlying some glacial bowlders. No fossils were seen in the quarry beds in place, but in some weathered blocks there were traces of Idiostroma, a form occurring at Iowa City below the level of the lithographic zone.

Exposures Near McIntire.—Limestone is exposed at the mill southeast of McIntire. It occurs in even and regular beds ranging from two to fourteen inches in thickness. As in many other cases, however, the stone is variable at the same horizon; any given bed may be unaltered limestone in one place and granular dolomite in another. On the south side of a small ravine south of the mill, a large amount of stone has been taken out. At one point the quarry face shows:

		FEET.	IN.
5.	Loess		6
4.	Decayed, magnesian, granular limestone	2	
3.	Laminated lithographic stone	3	
2.	Solid, granular, fossiliferous bed containing Stromatopora, Favosites, Atrypa, Spirifer and Cyrtina	1	3
1.	Thin-bedded, partly lithographic stone	2	

In some parts of the exposure the upper portion of No. 2 weathers into thin, irregular, earthy chips; in places it is solid lithographic stone. In the small creek bed between the quarry and the mill there are firm, dolomitic beds below the level of No. 1, six to eight inches in thickness. In a small opening north of the ravine the lithographic characteristics of 2 and 3 are better developed and approach in perfection of fineness and homogeneity some of the best examples of lithographic stone southwest of Osage. The McIntire quarries on the Wapsipinicon, in the northeastern part of the county, include the beds that are quarried near the top of the exposures around Osage and Orchard, in the valley of the Cedar.

GENERAL DEVONIAN SECTION.

		FEET.
8.	Magnesian limestone above the lithographic zone, represented usually by weathered chips	6
7.	Lithographic zone	9
6.	Assemblage of variable beds between the lithographic zone and the evenly bedded quarry stone	15
5.	Quarry stone, No. 4 of the Chandler cliff section	10
4.	Athyris bed	12
3.	Coarse, vesicular bed with calcite-lined cavities	5
2.	Regularly bedded dolomite at base of Chandler section	15
1.	Folded and brecciated zone	15

Pleistocene System.

KANSAN STAGE.

Kansan Drift.—The Kansan stage is represented in Mitchell county by the Kansan till and the Buchanan gravels. Over the greater part of the county the deposits of the Kansan stage have been concealed by the later Iowan; but in the pronounced loess-Kansan areas extending from above Mitchell to below Osage, there is no Iowan drift. This region seems never to have been occupied by Iowan ice. The surface deposits are made up of loess resting on residual clays or on weathered and reddened Kansan till. On the hill south of the west end of the bridge at Mitchell there are good exposures showing the red ferretto zone of the Kansan overlain by a heavy body of Iowan loess. The same relations are shown on the hills west and southwest of Osage. A possible explanation of the absence of Iowan drift, and the development of loess-Kansan characteristics in the axis of the Cedar river trough, is given in connection with the discussion of the topography of this anomalous area. The unweathered blue Kansan till, with splintered fragments of wood from the Aftonian forests, is exposed in wells and other artificial excavations. It underlies the surface over the greater part of the county.

Buchanan Gravels.—Buchanan gravels, laid down, as described in the report on Howard county, in the form of eskers, valley trains and outwash aprons, at the time of melting of the Kansan ice, are extensively developed in Mitchell county. There is a typical pit of the upland phase of the gravels a short distance southwest of Osage, in the northwest ¼ of section 35, township

98, range 17. The deposit is very ferruginous and weather stained. Most of the crystalline pebbles are profoundly altered and decayed. The section shows four feet of very rusty, cross-bedded sand overlain by from four to six feet of coarse, fer-

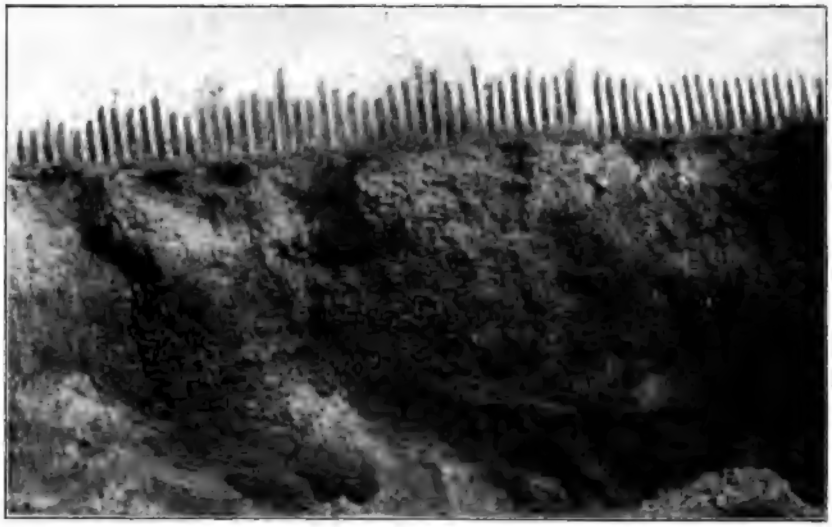


FIG. 53. Pit of Buchanan gravel overlain by Iowan loess, in the northwest quarter of section 35. township 98, range 17.

ruginous gravel (Fig. 53). Along with the northern granites and greenstones are some fragments of the local lithographic limestone, and it is interesting to note that the limestone has suffered less from weathering than most of the crystalline pebbles. Above the gravel is a mantle of fresh Iowan loess. There is no Iowan drift. The pit is located in the midst of an area of pronounced loess-Kansan topography, on a knob which rises eighty feet above the level of the river. Low ground to the south and southeast of the knob has evidently been occupied by Iowan ice. A short distance west of Mitchell is another pit of rusty Buchanan gravel similarly located in a loess-Kansan area which rises conspicuously above the level of the adjacent Iowan plain.

Beds of Buchanan gravel are to be found in every part of the county. Trains of gravel follow the valleys of the Wapsipinicon and the Little Cedar. Along the Cedar river the gravel occurs most frequently, not in the valley, but on the bluffs overlooking

the stream. At Mitchell, for example, old, ferruginous gravel lies on the summit of the cliff illustrated in figure 51. Extensive deposits are also found on the uplands remote from streams. It is not practicable to mention specifically all the outcrops; the deposits seem to be most common in Jenkins and Douglas townships.

IOWAN STAGE.

Iowan Drift.—The yellow clays and large coarse granite bowlders of the Iowan drift are distributed over nearly the entire county. No fresh railway cuts or well sections were seen, from which details relating to thickness could be obtained, but the level or slightly undulating topography, so universal in all the spaces between the major streams, affords trustworthy evidence concerning the geographical distribution of this comparatively young sheet of till. Figure 42 illustrates two characteristics of the Iowan drift—first, the level, unbroken, uneroded plain in which the surface remains precisely as it was left at the time of the withdrawal of the Iowan glaciers, and second, the large, coarse, granite bowlders which in some areas are liberally sprinkled over the surface. Compared with Chickasaw, Bremer and Buchanan counties, large bowlders are very rare in Mitchell. That shown in figure 42 is the largest seen in this county.

Iowan Loess.—The large loess-Kansan area beginning above Mitchell and extending to the southeast ¼ of section 36, township 98, range 17, a mile and a half south of Osage, is covered with a mantle of typical Iowan loess. In accordance with its habit near the Iowan margin, the loess is thickest on the highest points. It is always best developed on surfaces that never received any deposit of Iowan drift, surfaces that were never overflowed by Iowan ice, surfaces that, at the time of loess deposition, were extra-marginal so far as the Iowan glaciers were concerned. The conditions for loess deposition were met, even long distances back from the actual Iowan margin, whenever prominent areas of any kind or size rose above the level of the glacier surface. All the hills south and west of Osage rise above the level of the adjacent Iowan plain, and all are loess-covered. A cut made to accommodate the wagon road in the southeast ¼ of section 27, in Osage

township, reveals a section of rather dark-colored and siliceous, granular loess eleven feet in thickness. A little more than a mile south of main street, Osage, the road between sections 35 and 36 cuts through a heavy bed of typical yellow loess indistinguishable from that occurring around the Iowan margin in Delaware and Dubuque counties. At Mitchell there is a good section of loess a few rods west of the wagon bridge; there is another on the hill slope south of the bridge; other sections, too numerous for specific reference, occur throughout the Osage-Mitchell, loess-Kansan island. By comparing figures 46 and 42, the differences in the topographic features of loess-Kansan areas and the average Iowan plain may be readily appreciated. Typical loess is developed along Spring creek, a very good illustration occurring in the northwest ¼ of section 32, township 98, range 17. Loess also occurs along the Little Cedar at various points between Stacyville and the southern line of the county. There is a small area of loess-Kansan along Rock creek, in sections 8 and 17, township 97, range 17, and there is quite a bed of loess above the rock section at McIntire.

Supra-Iowan Loess.—Some of the loess of Mitchell county is distributed in a manner that is altogether unusual in regions near the actual Iowan margin. Superposition of loess on Kansan drift, or on any drift older than the Iowan, is the relation generally observed, but loess on a level Iowan plain is so unusual as to excite surprise. Nevertheless, in Mitchell county, there are extensive areas of the average Iowan plain covered with a thin veneer of gray or ashen loess, from a few inches to a foot in thickness. A broad belt of this thin loess, three to six miles in width, occurs west of the Little Cedar, a concrete example of which may be seen on the west side of the stream along the line between Lincoln and Douglas townships, and for two miles or more along the same line projected westward in the northern part of Lincoln. A part of the same belt is well shown in the vicinity of Stacyville. West of the Cedar there are a number of areas veneered with the thin gray supra-Iowan loess. An instructive illustration was noted in the south half of section 17, township 98, range 17, where the rain-cut trenches by the roadside showed from eight to ten inches of loess superposed on Iowan till. The gray pebbleless

loess was sharply set off by color and composition from the yellow glacial till with its numerous pebbles and cobblestones. It was set off from the till in another way, for the two deposits are not eroded with equal facility, and an overhanging shelf of loess formed a projecting cornice along the upper part of the walls of the small gullies. The same facts may be observed northwest of Mitchell, some distance away from the borders of the loess-Kansan island. This same type of loess is well developed in the region about Mona. On these loess areas the soil in the cultivated fields shows much lighter in color than the black loam developed on ordinary Iowan drift.

Iowan Terraces.—Sand terraces of Iowan age were seen at intervals along the valley of the Cedar river. Similar deposits may be present in the valleys of the other streams, but none were noted. A broad terrace, rising fifteen feet above the present flood plain of the river, occurs in the northwest ¼ of the northwest ¼ of section 34, township 98, range 17. The sand used in connection with building operations at Osage comes largely from this locality. Cross bedding is a common feature of the deposit. The upper zone for two feet or more is stained with humus, but the rest is clean quartz sand as fresh and unaltered as when it was laid down. The material is young as compared with any phase of the Buchanan gravels. The deposit is to be correlated with the fresh terrace sands of Iowan age occurring along the Iowa river near Iowa City. The difference in age between these young, fresh sands deposited from floods when the Iowan ice was melting, and such old weather stained, ferruginous sands and gravels of late Kansan age as are illustrated in figure 53, is almost immeasurably great. Near the center of section 21 of the same township there is another broad terrace of Iowan sands covering an area of several acres. Like the preceding its upper surface is not more than fifteen or twenty feet above the level of the water in the river.

Deformations and Unconformities.

The folding and crushing seen in the brecciated zone at the base of the Devonian section (Figures 49, 50 and 52) afford the only examples of deformation of geological strata seen in the county. The only unconformities worthy of note are those between the

glacial deposits and the Devonian limestones, and between the eroded surface of the deposits belonging to the Kansan age and the overlying Iowan drift and Iowan loess.

Soils.

The soils of Mitchell county are not very varied, but all possess a high order of merit. One type, the rich black loam developed on the surface of the Iowan drift, is the most widely distributed and covers much more than half of the entire area. On account of its general distribution it may be regarded as the characteristic soil of the county, and in all respects the most important. In point of quality it is equal to the best. This soil is rich in organic matter and in all the forms of plant food that arise as primary or secondary products of organic decay. The Iowan till is also rich in lime carbonate and other soluble mineral substances, a quality which makes this soil especially well adapted to the production of cereals and grasses. Both phases of the loess,—the thick yellow supra-Kansan and the thin gray supra-Iowan,—give rise to soils of excellent quality. All the soils of the county are mellow and easily cultivated, and so are in striking and agreeable contrast with the stiff, intractible clay soils of many less favored regions. The soils will always be the chief source of wealth, agriculture will always remain the principal industry of the county. On these facts the people of Mitchell county may well congratulate themselves. Agriculture is the noblest of callings. Every man engaged in it contributes something to the success and well being of humanity. It offers sure rewards to intelligently directed effort as no other occupation can. It affords an escape from labor troubles and from contact with the vice and poverty and wretchedness that develop to such an alarming extent around some of the great organized industries. It produces the best types of self reliant manhood and womanhood, and this is a contribution to the state and to humanity at large that is better than wealth.

ECONOMIC PRODUCTS.

Building Stone.—Exposures of Devonian limestones and dolomites are unusually numerous in this region when compared with other prairie counties, and so no neighborhood is very far re-

moved from quarries of available building stone. All the quarries and openings of special importance have been previously noted in discussing the typical sections of the indurated rocks. The principal horizons from which building stone is obtained are the lithographic zone and the regularly bedded dolomite numbered 4 in the Chandler cliff section. Southwest of Osage the lithographic limestone is quarried more than any other, while near Mitchell and St. Ansgar it is the dolomite that is worked the most. Along the Little Cedar from Stacyville to Brownville the quarries are mostly operated in the dolomitic horizon, but at McIntire on the Wapispinicon, the lithographic stone is included in the beds from which building material is obtained. West of the Cedar, the quarries on Rock creek work the equivalent of the lithographic zone. The Athyris bed becomes usable and is quarried near Otranto, and there appears no good reason who the dolomite numbered 1 of the Chandler section should not be found as useful as any other. At present there are no shipping quarries in the county. All now worked have been opened to meet the immediate local demand.

Lime.—All the lime at present burned in the county is made from the fine-grained, non-magnesian lithographic stone. The largest producer is Mr. George Lewis who operates a large draw kiln southwest of Osage. Work is not carried on continuously for the reason that the amount produced is governed by the demand in the local market. The lime is of good quality and serves an excellent purpose if used soon after it is burned. It has the disadvantage of all non-magnesian limes in that it air slacks readily, a fact that interferes with its being shipped far or kept in stock for any length of time. Lime is also made by Mr. Ritter one-half mile northeast of the Lewis quarry, the stone used being from the same lithographic horizon. Some of the dolomite which lies below the lithographic stone would make a lime having better shipping and keeping qualities than that now produced. Lime from dolomite is also intrinsically better than that made from pure limestone in the fact that it sets more slowly, sets harder, and makes a firmer bond.

Lithographic Stone.—The beds of the lithographic zone are known to range from Le Roy in Minnesota to Iowa City in

Johnson county, Iowa. In general they lack the fine even grain which would make them useful in lithographic printing; but the band comprising the upper eight or nine inches of No. 3 of the Lewis quarry section is remarkably fine-grained and homogeneous, and test samples of it were sent to the great lithographing establishment of A. Hoen & Co. of Baltimore. Reports of the tests were very favorable, in the language of one communication the stone "is quite as satisfactory for the finer process of lithographic engraving as it is for the ordinary transferring and printing processes." On mailing a few transfer impressions pulled from the sample of lithographic stone submitted for trial, the statement was made that "these impressions are as good as the original would give and, if defective, the defects are due to the original and not to the stone from which they were printed." The lower part of No. 5, as well as the upper part of No. 3, seems to be fine enough for good lithographic work. The only discouraging feature of the case lies in the fact that, so far as the quarries have been opened the beds are badly checked as shown in figures 47 and 48. making it difficult to get slabs of useful size. To have commercial value the quarries should be capable of affording pieces ranging from 30x42 inches up to 42x64. It may be possible that, as the quarries are worked farther in from the surface, the objectionable checks may not be so numerous, and that Mitchell county may add to its industries the production of a high grade of lithographic stone.

Road Materials.—The general distribution and the great number of rock exposures in the county bring the possibility of using crushed stone for road improvement within reach of almost every neighborhood, and the time will certainly come when many of the more important roads will be covered with macadam. Buchanan gravel is also available in almost every part of the county and offers a means for the improvement of the highways at once cheap and convenient.

Clays.—The Pleitocene deposits contain the only clays seen in the area under discussion. Glacial clay from either of the drift sheets contains so many pebbles as to interfere somewhat with its use in the manufacture of brick, tile and other

clay products, though, in the case of the yellow Iowan drift at least, the difficulties are not insurmountable. On the other hand the loess clays are too siliceous for use. No clay working plants are at present operated in the county.

Iron Ore.—Small beds of limonite are found at various places throughout Mitchell county. A fairly typical example of these deposits occurs a few rods east of the bridge which spans the stream a short distance northeast of the village of Little Cedar. Neither the thickness nor the extent of the ore body at this point could readily be ascertained. By far the most important deposit of iron ore is seen at the top of the bluff, a few rods north of the west end of the bridge at Mitchell. The bed is concretionary, but quite solid. A thickness of sixteen feet is exposed. The ore lies in an old channel cut in the Devonian limestone. There are many quartz pebbles included in it. Masses ranging up to six feet in diameter are found on the steep slope between the bottom of the ore body and the level of the water in the river. The ore at this point is at least pre-Kansan in age, for it is overlain by a bed of typical Buchanan gravel which, in turn, is overlain by the much younger Iowan loess. The lateral limits of the ore body could not be ascertained on account of the heavy mantle of younger deposits which effectually conceal it from view, but concretionary masses of the limonite were seen in the wash by the roadsides on the west side of the river, more than a quarter of a mile back from the bridge.

Coal.—For many years there has been a great deal of interest felt by the people of Otranto in .supposed indications of coal The black, carbonaceous band running through the quarry in the southeast ¼ of the northwest ¼ of section 28, township 100, range 18, has been noted on a preceding page. Wells at a number of points in and around Otranto have penetrated this black shale, and hopes of finding workable coal have been aroused and persistently entertained. Near Mona, according to report, a well driller found two inches of coal at a depth of thirty-eight feet, and six inches at a depth of forty feet. It is said that drilling stopped in light shale, but the depth of the light shale could not be ascertained. At less than 100 feet the Maquoketa might be reached. It is needless to say that there

is no coal of commercial importance in strata of Devonian age. Black seams with thin films of real coal are known to occur in the Independence shales at Independence, Iowa, and the same carbonaceous Devonian shale has been encountered at many other points, raising false hopes and leading to no small amount of useless expenditure.

Water Supplies.

The three principal streams of the county are permanent and afford bountiful supplies of stock water to farmers and others living along their banks. Most of the smaller streams are intermittent. For water supplies for all purposes, therefore, the people, over by far the larger part of the county, are dependent on wells. In some localities well water is obtained in seams of sand and gravel in the drift; but in Mitchell county the Pleistocene deposits, over large areas, are unusually thin, and a large proportion of the wells penetrate the limestones to greater or less depths. The area of deepest drift lies between the Wapsipinicon and the Little Cedar, where farm wells range in depth from 200 to more than 300 feet without striking rock. Quite a number of the wells in the deep drift of Jenkins, Douglas and Lincoln townships are reported as flowing. One in the northeast $\frac{1}{4}$ of section 17, Douglas township, is said to have a pressure of forty pounds to the square inch at a height of five feet above the surface. Between the Cedar and the Little Cedar the limestones generally lie nearer the surface; in some instances they come so near as actually to be exposed by wash in the roads and fields. The drift here rarely exceeds 100 feet in thickness; more commonly it ranges from twenty to sixty. In this region the water supplies are drawn from fissures at varying depths in the Devonian limestones. The well in the southwest $\frac{1}{4}$ of section 8, Burr Oak township, in which the drill passed through twenty-two feet of drift and went into rock to a distance of 133 feet, is rather an extreme case, but fifty feet in drift and eighty feet in limestone would be fairly typical of the wells of this region.

The city of Osage is supplied with water of excellent quality from an artesian well. The well is 780 feet deep and ends in the Saint Peter sandstone. No systematic record of the boring

was kept until a depth of 490 feet was reached, after which samples were carefully taken and a very satisfactory record is available. Through the kindness of Mayor Humbert the Survey was supplied with a set of samples from which has been compiled the following section of the strata penetrated by the drill:

		THICKNESS.	DEPTH.
14.	Light buff, crystalline dolomite, beginning at a depth of 490 feet, represented by four samples at 490, 520, 530 and 540 feet in depth respectively	50	540
13.	Limestone effervescing freely in cold hydrochloric acid, light gray in color, six samples at 560, 575, 585, 595, 600 and 625	85	625
12.	Yellowish limestone with pyritic crystals and small nodules, two samples at 630 and 640	15	640
11.	Light gray limestone with pyrite, one sample	5	645
10.	Dark gray limestone mixed with small chips of lighter gray from No. 11, some grains of pyrite, one sample	10	655
9.	Dark gray shaly limestone, pyritic, one sample	5	660
8.	Dark gray limestone mixed with chips of green shale	10	670
7.	Greenish shale	5	675
6.	Slaty gray shale with some small flakes of limestone and crystals of pyrite, two samples at 690 and 695	20	695
5.	Dark green shale with a few small bits of limestone and grains of clean, white, water-worn, quartz sand	20	715
4.	Clean, clear, water-worn, quartz sand mixed with some chips of green shale from No. 5, three samples at 725, 740, and 750, sand at 750 a little finer that that above	35	750
3.	Yellowish sand finer than any in No. 4	10	760
2.	Greenish, marly shale with some sand grains and small chips of limestone	10	770
1.	Fine gray sand with well rounded grains, some shale	10	780

In this section numbers 1-4 are Saint Peter sandstone. Numbers 5-13 represent the non-dolomitic phase, and 14 the dolomitized phase, of the Galena-Trenton. In addition to the samples noted in the section above, there are two others that presumably

come from points above the 490 foot level. They are marked No. 1 and No. 2 respectively, but no depth is given in either case. No. 1 is a mixture of light green and dark gray shale which might possibly come from the Maquoketa formation. No. 2 is a light colored limestone.

At St. Ansgar a well was in the process of boring. The drill had reached a depth of 160 feet, the last sixty feet being in the Maquoketa shales.

Water Powers.

Water powers have been developed on all the three principal streams of the county. For example, there are mills on the Wapsininicon at McIntire and Riceville. Mills have been built at Stacyville and Brownville on the Little Cedar. On the Cedar river there are mills at Otranto, Newburg, below St. Ansgar, at Mitchell, and at a point two miles west of Osage. That west of Osage illustrates the manner in which all possible water powers are certain to be utilized in the future, namely, in the development of elctrical energy and its transmission to points where it may render service to the inhabitants of town and farm.

SUMMARY.

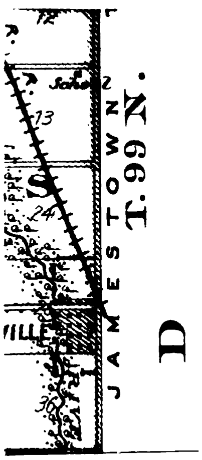
Mitchell county lies wholly within the Devonian area and within the area properly belonging to the Iowan drift. The valley of the Cedar river is the bottom of a broad trough in the surface of northeastern Iowa, which has Cresco and Calmar on one rim and Wesley in Kossuth county on the other. Northeast of the Cedar the general surface slopes strongly toward the southwest, but the streams of the region—including Crane creek, the many branches of the Wapsipinicon, and the Little Cedar—flow toward the southeast, their courses being nearly at right angles to the direction of the greatest slope. The position of the Cedar river, at the bottom of the great trough, probably explains the unusual preglacial characteristics of the valley and the presence of loess-Kansan islands so far from the actual margin of the Iowan drift.

The indurated rocks are Devonian limestones and dolomites, they all belong to one stage, and the aggregate thickness of all

the beds exposed in the county does not exceed ninety feet. The dip of the strata coincides very nearly with the general slope of the surface, and so practically the same beds are seen at the numerous points where indurated rocks are exposed. The lithographic zone, which is so constant a feature of the Devonian limestones of Iowa, is unusually well developed, and certain parts of these beds are fine grained and homogeneous enough to be used in the better grades of lithographic printing, provided blocks of the desired sizes can be obtained. Quarry stone suitable for rough masonry is abundant and is available in almost every part of the county. Material for lime making is plentiful and of good quality. Workable clays are scarce. There is no possibility of finding coal. It is possible, and highly probable, that in the future quarrying and lime burning will be developed into industries of far greater importance than they have yet attained. With the splendid quality and inexhaustible resources of the soils of the county, agriculture and related industries must always remain the principal occupation of the people, the chief productive source of wealth.

ACKNOWLEDGMENTS.

In prosecuting the field work in Mitchell county the writer was ably assisted by Professor F. M. Arey of the Iowa State Normal School. Without this assistance the work could scarcely have been finished in the time available for operations in the field. Of the great value of the volunteer services rendered by Professor Arey, and of the aid so generously extended by all the citizens of the county with whom the work brought the representatives of the Survey in contact, it is a pleasure to make grateful acknowledgment.



MITCHELL

COUNTY
IOWA.

BY

SAMUEL CALVIN

1903

DISCUSSION OF THE

Requisite Qualities of Lithographic Limestone,

WITH

REPORT ON TESTS OF THE

Lithographic Stone of Mitchell County, Iowa.

By A. B. Hoen.*

In order that a good understanding may be had of the subject of this article, it will be necessary to give a description of the process of lithography and the principles on which it depends for its successful working. These principles are very simple in nature.

In the dawn of the preceding century Alois Senefelder, a young Bavarian playwright and composer, to save expense, sought some cheap means of producing editions of his works. He first tried copper engraving, but as the plates were quite expensive and the use of the same plate for subsequent engraving involved the tedious grinding out of the existing engraving and the resurfacing of the metal, he found his means and time inadequate. He had been using slabs of Solenhofen limestone as mortars on which to grind and mix his copper plate inks. In the absence of a suitable piece of paper, he one day made a memorandum on a clean

*As noted in the body of the report on Mitchell county, samples of the lithographic stone from the quarries near Osage were submitted for trial to the lithographing house of A. B. Hoen & Company, Baltimore. Mr. A. B. Hoen generously undertook the task of subjecting the stones to all possible practical tests. For this service, and for the accompaning discussion of the qualities which a serviceable lithographic stone must possess, the Survey gratefully acknowledges its obligations. Plate VIII, printed on a sample of the stone from Mitchell county, illustrates the quality of the work which may be done with lithographic stone from Iowa. S. C.

slab of this stone, using as ink a fluid made of wax, soap, lamp-black and water. He had previously used this same preparation to cover up mistakes in his copper engraving before etching. It occurred to him, on looking at the dried writing on the stone, that the same ink might offer a good resistance to acid and that, perhaps, the letters might be brought into relief by etching and then used, as wood blocks were, for surface printing. Etching with nitric acid proved the correctness of his reasoning and he was able to ink letters, now standing in relief, with an ink ball or tampon and to obtain prints from the inked surfaces by applying paper under pressure. This, happening in 1798-99, was the beginning of lithography. The new art was soon in great demand, its principles were taught to some qualified disciples and its practice was begun in many places. Senefelder in 1818 produced an extensive treatise on his art, which easily supplanted all previous writings on the subject. It will be noticed, however, that the plates resulting from the process as described, differed in no essential feature from those of the typographer of that day or of the present. The design or lettering to be printed was made to stand in relief, so that only the raised surfaces would take ink from the inking roller and, in turn, communicate the impress to the printing paper. From the beginning, as made by Senefelder, came several unexpected results. It was found, if ink containing soap or grease were used to make the drawing on stone, that it was not necessary to etch the design into high relief, but that the greased parts would take ink and the ungreased parts would remain clean, provided the stone was kept damp during the operation of inking. This was the greatest advance made in the art since its discovery and indeed is the basis of modern lithography.

The Solenhofen stone is a compact, amorphous limestone. The cleanly polished surface will absorb water, not as rapidly as chalk, but in the same manner. It is porous. Therefore such a surface, the mass having an affinity for water, can be kept evenly moist by wiping or rolling with a wet sponge or cloth. As long as the surface of the stone is moist, grease and greasy or oily inks will not attach themselves to it. They are prevented, by the film of water, from actual contact. Conversely, if the clean, dry surface be covered with grease or varnish, the pores of the stone will

be filled and the stone will be no longer capable of absorbing water through its greased surface. Even if water be poured on such a greased stone, it would not moisten it with an even film, and an inking roller would secure contact with the surface and discharge the ink.

Making use of the repugnancy of grease and water for each other and of the power of the stone to absorb, we should expect and find that a design traced or drawn with greasy ink or greasy crayon on a clean stone, would fill in the pores of the stone in those parts covered by the design, and that the same parts would locally repel water and attract grease or greasy ink.

The application and improvements of mechanical devices to the carrying out of this fundamental principle mark the stages in the progress of lithography from the time of its discovery to the present.

It might be asked, is the compact amorphous limestone the only material that will respond to this dual treatment with water and grease? By no means. Grained glass will carry a grease design for a short time, but if the grease be washed out of the grain with some solvent, the design will be found to have disappeared and cannot be developed by further application of ink and water. A design or image formed on lithographic stone may be washed out so that none of the ink remains on the surface, but may be brought back by treatment with water and ink together—the ink taking to the previously greased parts and the water keeping the previously clean parts from taking ink. These two sets of phenomena lead to an explanation of the principles underlying the lithographic process. The image on the glass could be removed completely by solvents of grease, but the image in the stone was more firmly seated and could not be removed by these media. Evidently the stone was affected by the grease in a way different from the glass. My experiments have shown that if fixed vegetable or animal oils be brought in contact with clean dry limestone, they will penetrate it, mechanically fill its pores. and thus make a printable image. This image, however, may be removed if solvents, such as benzene, be copiously applied shortly after the oil and stone have been brought together. Prolonged action of the oil on the stone leads to a chemical as well as physi-

cal union, i. e., the fatty matter not only fills in the pores of the stone, but also replaces the carbon dioxide (CO_2) of the stone and forms a calcium salt of the fatty acid. This calcium salt is insoluble in both water and grease solvents and the image thus formed is therefore permanent. An image of like permanency may be formed by impregnating the stone with some light sensitive material which will attract grease and repel water—asphaltum for instance. If an image be formed in the stone with thin asphalt and be rendered insoluble in turpentine by exposure to sunlight this image will behave, for all practical purposes, in the same way as the fatty-acid lime salt. When such an image is inked in the usual way the grease of the ink ultimately combines with the lime and the resulting image is the same as previously formed by direct application of grease or oil to the clean stone.

As stated above, the formation of the fatty-acid lime salt, say calcium oleate, may be prevented by solvents if the latter be quickly applied. The combination takes place much more rapidly if the fatty acid itself be used in place of its glycerine salt.

The most efficacious means of all, however, for producing this combination is by the double decomposition of an alkali salt of the fatty acid (soap), and the stone by means of one of the mineral acids. In other words, if the image be drawn or laid down on the stone with crayon containing soap and then etched with a solution of hydrochloric acid, the soda of the soap will be taken up by the hydrochloric acid (HCl), the fatty acid will be set free and will combine immediately with the lime of the stone to form a lime soap. This forms the latent image in lithography and when the stone is washed clean with water and turpentine it may be faintly seen by reason of the difference in color of the calcium oleate from the surrouning carbonate. The latter too has a matte or etched appearance on account of the action of the hydrochloric acid (HCl).

While the acid fixes the greasy image in the stone, it has a further role to play in keeping the ungreased parts clean. It was found in practice that acid (HCl or HNO_3) and the calcium salts resulting from its action on the stone were far better than

plain water in keeping the open parts—the ungreased parts—clean. They filled the pores of the stone and, even if the stone dried, prevented combination with grease fortuitously coming in contact with it. A still further improvement in this direction was made by the addition of gum arabic or similar colloid substance to the etching fluid. The gum penetrates the surface of the stone and forms a film on it and at once prevents the taking on or spreading of the greasy ink and at the same time is ever ready to take up moisture. So firm a hold has the gum on the stone that if a clean stone be gummed and the gum allowed to dry, oil or greasy ink may be smeared over this gummed surface without affecting the stone, which will come out perfectly clean on application of water.

With these principles in mind we may now look into the two major subdivisions of the lithographic art, consideration being had for the characteristics of the stone which facilitate or impede its practice.

The first process is to apply the grease locally by means of fine pens or brushes to the surface of a clean stone. If the stone had been previously grained with fine sand the local application of the grease may be made with lithographic crayons, which are composed of lamp black and hard soap.

The gradation of shading may be produced with crayon on these grained stones just as it would be on grained drawing paper. When the drawing is complete a solution of acid and gum in water is poured or brushed over the stone. By this operation, termed etching, the grease or soap of the crayon is fixed in the stone and at the same time the clear parts of the stone, even the minute spaces between points of the grain, are filled in by the acid gum solution. After the gum has dried the ink or crayon of the drawing may be washed off with turpentine and the gum with water. While the water is still on the stone the image or delineation can be seen by reason of its remaining dry while the other parts hold the water. At this stage passing an ink-charged roller over the stone will bring the roller in contact with the dry parts which will take ink and reproduce the original drawing. The stone is now ready for printing by application of paper under pressure.

The second method is the reverse of this operation. It consisits in etching or gumming the stone first and after the gum has thoroughly dried to engrave or cut through the gum and into the stone, so that wherever the design is cut in, the virgin stone is exposed. After the engraving has been finished the whole surface of the gummed stone is covered with oil, which is rubbed into the engraved lines and allowed to act on the stone for a half hour or less. The stone is protected by the film of gum, except in those places that have been laid bare by the graver and it is just these places that are affected by the grease.

The stone is kept moist while printing ink is rubbed or "daubed" into the engraved lines. On account of their being greased, these lines readily take ink and when properly charged yield impressions on paper that is forced into the lines by pressure. On account of the slowness and difficulty of printing these engraved stones, they are seldom used as plates from which an edition is to be printed. On the other hand, the finest kind of line work, such as maps, script, lettering and in fact all kinds of work formerly done on steel or copper, can be successfully imitated on fine grained lithographic stones.

In order to print this engraved work with commercial economy, the engraving is inked with fatty ink, an impression is taken on starch-coated paper, and this impression is laid down on a smooth, clean stone and the two are brought into close contact by repeated application of pressure. The greasy ink leaves the paper, attaches itself to the clean stone, is treated with gum and acid and a replica of the engraving is thus attained wherein the lines are on the surface of the new stone in place of being depressed, as on the original. This process is the same in principle as that described under the first method, i. e., it is a direct local application of the grease to the clean stone. It differs only in method of application. These transfers, as they are called, are used for power press printing. A further advantage derived from transferring lies in the fact that the design transferred may be repeated on the new stone as often as the dimensions of the design will go into those of the new stone. Thus an octavo plate (6x9½ inches) may be repeated eight times on a 19x24 inch stone and every impression of the latter will yield eight copies of

the original engraving. It is principally through this transferring process that stones of large size have lately come into demand. A natural limit to the sizes of the stones is reached when their increased weight and the mechanical difficulty of handling large sheets of paper become factors of economic importance. So it is that stones measuring 42x64x5 inches and weighing about 1,200 pounds are the largest that are in daily use. Indeed even these sizes seem to be almost too large for safe handling so that 36x52 inches is a much more popular size.

It was stated that drawings made on glass could be made to yield a few impressions, but that the image lacked permanency, there being merely an adhesion of the locally applied ink to the glass. Glass is neither porous, nor does it combine chemically or physically with grease. On the other hand, we found that lithographic stone had the power not only of receiving the image, but also of retaining it. Between these extremes of glass on the one hand and stone on the other come those materials which have found more or less extended use in the lithographic process. Zinc and aluminum are the chief of these substances. Both are inferior to the best stone, taking the quality of the work into account, and especially in the matter of control while in the printing press. Aluminum printing, however, has been brought to such a stage that for some kinds of work it offers economic advantages, such as lightness, cheapness, flexibility (adaptation to rotary presses) over stone, and, on this account, has been a formidable rival of stone printing in recent years. However, for the finest work nothing has been found to equal the best grade of lithographic stone.

The process of practical lithography has been outlined and it is now proposed to consider lithographic stone and the qualities which make it fit for use in the art.

The essentials are chemical composition and texture. Color is a modifying attribute. The following analyses of different stones, each of which has been successfully printed, shows that the chemical constituents may vary considerably, notably the magnesium-calcium ratio. It is to be noted in this stage of our inquiry that the stone should be evenly etched on treatment with cold dilute acid. This will not be possible if the magnesium is

ANALYSES OF KENTUCKY AND BAVARIAN LITHOGRAPHIC LIMESTONE, AND OF STONE FROM MITCHELL COUNTY, IOWA.

	Brandenburg, Ky.*	Solenhofen, Bavaria.*	Mitchell Co., Iowa.†
INSOLUBLE IN HYDROCHLORIC ACID.			
Silica, SiO_2	3.15	1.15	.78
Aluminum-iron oxide $(AlFe)_2O_3$	.45	.22	Trace.
Lime, CaO	.09	Trace.	....
Magnesia, MgO	None.	None.	....
SOLUBLE IN HYDROCHLORIC ACID.			
Alumina, Al_2O_3	.13	.23	.12
Ferrous oxide, FeO	.31	.26	....
Magnesia, MgO	6.75	.56	.07
Lime, CaO	44.76	53.80	54.91
Soda, Na_2O / Potash, K_2O	.13	.07	.18
Humus	....	....	.11
Hygroscopic water, H_2O	.41	.23	....
Water of composition, H_2O	.47	.69	.35
Carbon anhydride, CO_2	43.06	42.69	43.16
Sulphuric anhydride, SO_3	None.	None.	Trace.
Total	99.71	99.90	99.68

* Chemical Laboratory of U. S. Geological Survey.
† Analysis by A. B. Hoen.

present in large proportion. The extent to which the isomorphous magnesium carbonate may replace the lime without affecting the working qualities of the stone, has not been determined. It is really a question of solubility in cold acid and the answer is to be sought by experimenting in this direction. Cold dilute hydrochloric acid, however, will readily etch a very impurelimestone when the impurities are mechanical admixtures of silica and alumina. These impurities remain in the solution of calcium chloride as a muddy sediment and the etched surface of the stone will show the roughness due to resistance of these insoluble particles to the acid. Impurities of this kind are very objectionable and, if present beyond a small percentage, unfit the stone for use for fine engraving. Besides the roughness in the etching, they are apt to make the stone uneven in texture, so that the graver would cut unevenly.

The low percentage of silica and alumina in the Mitchell county stone is remarkable and is a decidedly strong point in its

favor. The absence of hygroscopic water may be accounted for by the fact of the stone's having been for several months in a warm, dry room. Chemically, the points of difference between the Iowa stone and the German and Kentucky stones, favor the former.

There is a kind of impurity which would not show in analysis, yet is of serious nature when present even in small amount. It is the presence of crystals of calcite throughout the mass of the stone or in veins. Crystalline limestone does not absorb water evenly, nor combine with grease in such a way as to be subject to control. Again, on account of the unequal hardness of the crystals and the matrix, it is not possible to engrave easily and satisfactorily on a stone showing such defects. Calcite is usually confined to veins (faults), but occasionally is developed in the mass of the stone itself. German stones rarely show the latter phase. Of the several samples of Mitchell county stone, those taken from layers above those marked XX in the accompanying illustrations are badly marked, not only with the crystals in the mass, but by numerous marks of interruption in the process of sedimentation. A cross section made perpendicularly to the plane of deposition shows the presence of these irregularities in composition, as well as unevenness in texture.

In the polarising microscope sections taken even from the best layer, show a sprinkling of microscopic crystals of calcite and when these are crowded together they become apparent to the unaided eye as an unevenness in the otherwise unbroken color of the stone.

The best German stone also shows these microscopic crystals of calcite and indeed the whole amorphous groundmass of both the foreign and domestic stones seems to be bound together by this anisotropic medium.

The principal layer, however, is almost free from visible crystalline particles and it is from this layer that the sample stone from which the accompanying illustration was printed is taken.

Lithographic stone should be of even texture, amorphous, free from inclusions of grit and chalk. It should be hard enough to resist the graver to some appreciable extent, yet not so hard as to

make engraving difficult. This is a condition that is difficult to describe and cannot be expressed in terms of the common scale of hardness, although it is easily learned after a few trials with a knife point or needle.

The soft stones (yellow of the Solenhofen quarry) are too soft or "chalky" for fine engraving. The dark blue stones, on the contrary, are so hard that the engraver has to apply such force that the effort of holding his tool becomes tiresome and the tool itself quickly loses its point either by wear or by breaking. The hardest stones, however, will carry the finest lines, while similar work on soft stones appears rough and easily wears away. For these reasons stones of intermediate hardness, which embody the good qualities of both the extremes, are most in demand by lithographers and command the highest price. These degrees of hardness are accompanied, in the German stones, by a corresponding variation in color. The soft stones are of a yellow manila-paper tint, the hardest are a blackish gray, while the stones of intermediate hardness are of a grayish buff. So constantly do these colors vary with each other that stones, otherwise perfect, are listed, bought and sold, almost solely on the basis of their color. The Iowa stone is a lithographic anomaly in respect to its color. It is lighter in shade than even the softest of the yellow German stones, yet is of such fine texture and of such comfortable hardness that the engravers who tried it expressed themselves as much pleased with its behavior under the needle point. Of course, the tints of the German stone are the exponents of varying degrees of compactness, which in turn modifies in a direct or indirect way the more or less constantly present percentage of colored impurities. The very small proportion of coloring matter present in the Iowa stone, as compared with the others given in the analyses, affords an explanation of the anomaly above referred to.

As absorption of water is one of the two essential characteristics of lithographic stone, some experiments were undertaken to determine the relative absorbing power of the German and Iowa stone. To do this cubes of the stone were made with faces approximately 2 centimeters square. The surface presented was therefore 24 square centimeters. They were weighed in air and

again after immersion in water for twenty minutes with the following results:

Bavarian stone absorbed	.00270 grams.
Iowa " "	.00165 "

The same experiment was repeated, allowing the cubes to remain in water twelve hours. The absorption increased for both as shown below:

Bavarian stone absorbed	.0333 grams.
Iowa " "	.0156 "

These figures indicate that the Iowa stone, in spite of its light color, is denser and finer grained than its Bavarian relative. To determine in the case of the Iowa stone whether this absorption, so makedly inferior to that of the German, was sufficient for practical purposes, a slab of the stone about 14x20 inches was tried in the press, the printing being proceeded with in the usual way. No difficulty was experienced in printing an edition of several thousand copies of the work, which was a transfer of finely ruled commercial engraving. The colored illustration accompanying this article was printed from the same stone and it should be stated that the work was undertaken solely to test the printing qualities of the stone and not for any necessity for coloring in the illustration itself. Following up the absorption tests, others were made to determine the specific gravities of the two stones, which were:

Bavarian stone (gray)	2.69
Iowa " (pale cream color)	2.71

These figures accord well with what might be expected from the behavior of the two stones in the tests for absorption.

Lithographic stone is not restricted to any particular geologic age. The Bavarian stone is Jurassic; some from Texas, Cretaceous; from Kentucky, probably Carboniferous, while the stone, for which this comparison is made, is from the Devonian strata of Mitchell county, Iowa.

More significant than age is its mode of occurrence. The German stone lies in nearly horizontal layers, from an inch or two, up to a foot or more in thickness. The aggregate thickness of the

strata is 80 feet (Dana). It is not much disturbed from its original position. This is important, as disturbance produces faults and fissures which fill in subsequently with calcite or ferruginous cement, both of which are serious blemishes in an otherwise good stone.

The mode of occurrence of the Iowa stone can be seen in the illustration, Plate VIII. There is considerable variation in the quality of the stone from both the quarries shown. In the Gable quarry the best layer is the one immediately above the floor of the quarry. It is about 2 feet thick. The same stone is shown in the Lewis quarry with the hammer and rule leaning against the fine grained layer. The stone from this layer is apparently homogeneous, in the sample examined, with the exception of the bedding marks. It was noticed in trueing the stone for printing that the surface plane intercepted planes of bedding at small angle and, as these bedding planes always include foreign material, their intercepts with the plane face of the stone would be marked by an outcrop of this foreign material. The bedding planes appear to be not quite as true as in the Solenhofen quarries. Appreciable undulations or pits were noticed in the cleavage surface of the sample. It is hoped that further exploitation of the quarry will yield layers thick enough to be planed for use and at the same time free from checks and calcite inclusions. If layers are found in which the process of sedimentation has gone on uninterruptedly until layers of 2, 3 or more inches in depth have been laid down, there would be little doubt as to the unqualified excellence of the deposit. As Professor Calvin's examination was not carried beyond an observation of the stone exposed on the side of the hill and, as the sample submitted for trial was such a one as he could detach without the aid of a quarryman, there is reason to hope that, as the surface stone is removed, larger and more perfect slabs may be obtained from those portions of the deposit that have not been subject to atmospheric action.

The price of stone varies from 3½ to 17 cents per pound for good quality yellow German stones. The gray stones bring 50 per cent more. A table of the prevailing prices (for yellow stones) and corresponding sizes is given herewith.

Lewis Quarry, southwest of Osage, Mitchell County, Iowa.
X X *Beds of fine grained lithographic stone.*

Gable Quarry, southwest of Osage, Mitchell County, Iowa.
X X *Beds of fine grained lithographic stone.*

VALUE OF LITHOGRAPHIC STONES.

NO.	SIZE.	Price per pound.	NO.	SIZE.	Price per pound.	NO.	SIZE.	Price per pound.
		Cents			Cents			Cts.
*1	16x22	3½	13	26x36	8	*25	32x48	13
2	18x24	4½	*14	26x38	9	*26	34x48	13
*3	19x25	4½	15	28x38	9	27	35x50	14
4	20x26	5	*16	28x40	10	28	36x50	14
*5	22x28	6	17	28x42	11	29	36x51	14
6	22x30	6	18	29x43	12	*30	36x52	14
7	22x32	6	19	30x40	12	31	40x60	14
*8	22x34	7	20	30x43	12	*32	40x62	15
9	24x30	7	*21	30x44	12	33	42x60	15
10	24x32	8	22	32x43	12	34	42x62	16
11	24x34	8	23	32x44	12	*35	42x64	16
*12	24x36	8	*24	32x46	12	36	43x64	17

* The sizes marked with an asterisk are those commonly in use.

It is to be noted that for profitable production of lithographic stone there must be facilities for handling and there should be some market for the waste product. As the quarry must be conducted without blasting, the expense of the slower process of gadding or channelling must be taken into account.

For the information of prospective investors the following table of values of lithographic stone imported into the United States from 1868 to 1900, inclusive, is given:

YEAR ENDING JUNE 30.	VALUE.	YEAR ENDING JUNE 30.	VALUE.	YEAR ENDING DEC. 31.	VALUE.
1868	$ 13,258	1880	$ 56,310	1890	$ 105,288
1869	17,044	1881	77,894	1891	107,339
1870	14,225	1882	111,925	1892	107,777
1871	21,311	1883	104,313	1893	91,849
1872	36,146	1884	128,035	1894	74,454
1873	44,937	1885	54,022	1895	107,670
1874	36,902	1886	71,009	1896	74,044
1875	41,963	December 31		1897	58,922
1876	47,101	1887	83,182	1898	60,522
1877	44,503	1888	113,365	1899	86,695
1878	42,700	1889	78,077	1900	94,134
1879	37,746				

In recapitulation it may be stated that the Mitchell County stone is at least as good in quality as the Bavarian stone for lithography in all its branches and it remains to be determined

GEOLOGY OF MONROE COUNTY.

S. W. BEYER AND L. E. YOUNG.

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[illegible] BALTIMORE

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In recapitulation it may be stated that the Mitchell County stone is at least as good in quality as the Bavarian stone for lithography in all its branches and it remains to be determined

strata is 80 feet (Dana). It is not much disturbed from its original position. This is important, as disturbance produces faults and fissures which fill in subsequently with calcite or ferruginous cement, both of which are serious blemishes in an otherwise good stone.

The mode of occurrence of the Iowa stone can be seen in the illustration, Plate VIII. There is considerable variation in the quality of the stone from both the quarries shown. In the Gable quarry the best layer is the one immediately above the floor of the quarry. It is about 2 feet thick. The same stone is shown in the Lewis quarry with the hammer and rule leaning against the fine grained layer. The stone from this layer is apparently homogeneous, in the sample examined, with the exception of the bedding marks. It was noticed in trueing the stone for printing that the surface plane intercepted planes of bedding at small angle and, as these bedding planes always include foreign material, their intercepts with the plane face of the stone would be marked by an outcrop of this foreign material. The bedding planes appear to be not quite as true as in the Solenhofen quarries. Appreciable undulations or pits were noticed in the cleavage surface of the sample. It is hoped that further exploitation of the quarry will yield layers thick enough to be planed for use and at the same time free from checks and calcite inclusions. If layers are found in which the process of sedimentation has gone on uninterruptedly until layers of 2, 3 or more inches in depth have been laid down, there would be little doubt as to the unqualified excellence of the deposit. As Professor Calvin's examination was not carried beyond an observation of the stone exposed on the side of the hill and, as the sample submitted for trial was such a one as he could detach without the aid of a quarryman, there is reason to hope that, as the surface stone is removed, larger and more perfect slabs may be obtained from those portions of the deposit that have not been subject to atmospheric action.

The price of stone varies from 3½ to 17 cents per pound for good quality yellow German stones. The gray stones bring 50 per cent more. A table of the prevailing prices (for yellow stones) and corresponding sizes is given herewith.

Lewis Quarry, southwest of Osage, Mitchell County, Iowa.
XX *Beds of fine grained lithographic stone.*

Gable Quarry, southwest of Osage, Mitchell County, Iowa.
XX *Beds of fine grained lithographic stone.*

BALTIMORE

Coal Measures over almost the entire county and states that they are overlain by the Middle Coal Measures. In the same volume Professor Rush Emery gives the results of analyses made of several samples of coal obtained from the mines then in operation.

McGee* makes reference in his "Pleistocene Iowa" of a complex drift section exposed along the railroad south of Albia. Several references are made to the geology of the county in the reports of the present Survey, and due credit will be given where such references are used in this paper.

The reports of the State Mine Inspector, especially the early numbers, contain considerable information regarding the coal and Coal Measures stratigraphy. Some of the drill sections will be found in a later portion of this report.

PHYSIOGRAPHY.

TOPOGRAPHY.

Monroe county belongs to the dissected plain type of topography. It is typically erosional in character, the surface features conforming to the drainage lines. The ridge crests rise to about the same level and when produced roughly approximate the original plain before it was acted upon by the streams. A marked divide mapped out by the Wabash railway bisects the county into almost equal east and west halves. The streams on either side have worked headwards completely draining the area and producing very gentle undulations in the watershed even when viewed longitudinally. Albia is located on this watershed at a point where its direction changes from northwest-southeast to west of south and from which point the streams radiate in practically every direction. The divide when viewed broadly inclines gently to the north as indicated in the table of elevations; Moravia showing an altitude of 1002 feet, Albia 959, and Lovilia 932. The stream valleys and hill slopes are generally well wooded while the divides are prevailingly prairie. This is the general rule even in the case of the minor drainage lines. The maximum general inequalities vary from 677 feet, low water level of the Des Moines river at Eddyville, to about 1000 feet on the Albia-Moravia divide

*Sixth Ann. Rep. U. S. Geol. Surv., Vol. 493-4. Washington, 1891.

near the south county line. The local inequalities do not as a rule exceed 100 feet, although occasionally reaching about 150 feet. The entire surface is fairly well drained and may be designated as topographically mature. All of the topographic features may be ascribed directly to stream work and can best be understood when studied in conjunction with the drainage lines.

The elevations of the principal representative points in the county are given in the table herewith appended:

TABLE OF ELEVATIONS.

PLACE.	Altitude above tide water.	AUTHORITY.
Albia	959	Chicago, Burlington & Quincy Railway.
Brompton	950	Chicago, Milwaukee & St. Paul Railway.
Buxton	799.7	Chicago & Northwestern Railway.
Coalfield	727	Iowa Central Railway.
Consolidation Coal Company, Shaft No. 10	844.3	Chicago & Northwestern Railway.
Consolidation Coal Company, Shaft No. 11	948.7	Chicago & Northwestern Railway.
Des Moines River, Eddyville	677	Iowa Central Railway.
Dudley	697	Chicago, Burlington & Quincy Railway.
Eddyville	685	Iowa Central Railway.
Foster	904	Chicago, Milwaukee & St. Paul Railway.
Frederick	737	Chicago, Burlington & Quincy Railway.
Hagerty	946.2	Chicago, Burlington & Quincy Railway.
Hamilton	905.5	Chicago, Burlington & Quincy Railway.
Lovilia	932.3	Chicago, Burlington & Quincy Railway.
Melrose	891	Chicago, Burlington & Quincy Railway.
Moravia	1001.6	Wabash Railway.
Selection	973.3	Wabash Railway.
Tower	815	Chicago, Burlington & Quincy Railway.
Tyrone	839	Chicago, Burlington & Quincy Railway.

DRAINAGE.

The streams which have to do directly with the drainage of the county are unimportant individually with the exception of the Des Moines river, which barely truncates the northeast corner of the county. With this exception none of the streams are persistent through their entire courses during seasons of protracted drouth. During the exceptionally dry year of 1901 the majority of the streams which are shown on the map were entirely dry or reduced to a series of disconnected ponds and pools. In many instances, however, the isolated ponds gave no evidence of stagnan-

cy but indicated rather a sub-surface drainage connection through the stream gravels. Most of the streams have done considerable cutting even to the tributaries of the second order, fully draining the divides and giving the country a broken appearance

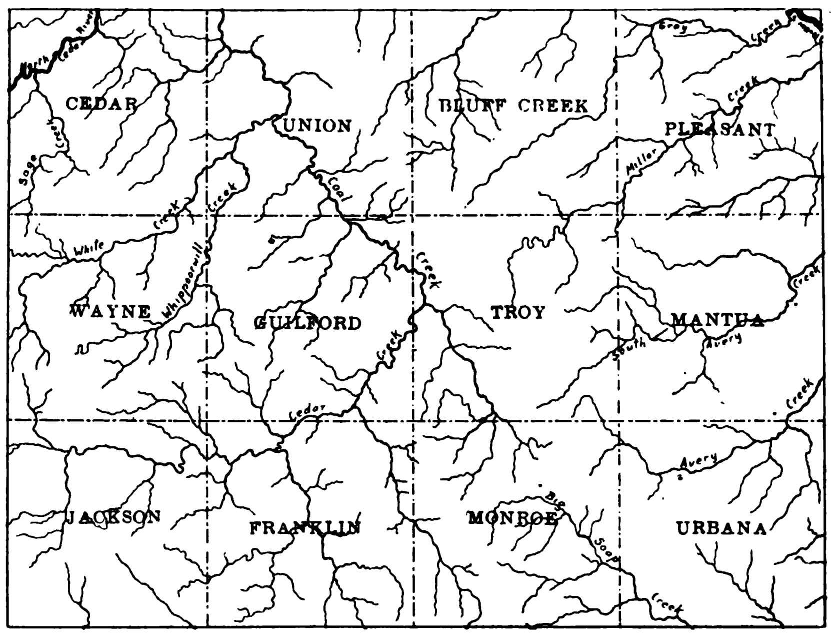

FIG. 51. Sketch map showing the drainage of Monroe county.

characteristic of south-central Iowa. While the work of degradation accomplished by the streams is great in the aggregate, their energies have been devoted chiefly to channeling and but little has been done toward the production of broad valleys and the upbuilding of flood plains. In fact but few of the drainage lines have mapable flood plains according to the scale used in these reports. While the distance from bluff to bluff may attain several hundreds of yards the steep slopes render obvious the instability of the materials and greatly limit the true flood plain deposits. The materials in many of the stream channels tell the same story by their coarseness in texture, evidencing the carrying power of the streams. This is notably true of all those directly tributary to the Des Moines river.

The Des Moines River System.—The Des Moines river, with its numerous tributaries, drains about thirty-nine fortieths of the county, the remaining fortieth finds outlet through the Chariton system. The most important tributaries of the Des Moines are Cedar river, Coal, Bluff, Gray, Miller, Avery and Soap creeks. A marked divide sought out by the Des Moines branch of the Chicago, Burlington and Quincy railroad and the Wabash and the Iowa Central below Albia, separates the tributaries of Cedar river, Coal creek and the Chariton river system from the easterly flowing feeders of the Des Moines. From the town of Albia the streams flow towards all points of the compass save northwest.

The Cedar river, whose confluence with the Des Moines is in Marion county, with its leading tributary Coal creek, drains more than half the county. Both streams flow almost due north as they leave the confines of the county and their most important branches flow in the same direction, paralleling the Albia-Lovilia divide. Cedar river proper drains scarcely half a township while Coal creek, with its sinuous bifurcating branches collects the run-off from half the county. Cedar river has a low gradient and presents a narrow flood plain. The indurated rocks are exposed only near the Marion county line.

Coal creek does not depart materially from the usual type of Iowa stream, being asymmetric and receiving the larger tributaries from the west, in fact, receiving none worthy a name from the east. From north to south the branches are White, Whippoorwill, Bee and Cedar; the last being the most important and draining all of Franklin and portions of Wayne, Guilford, Troy and Monroe townships. The main line of the Chicago, Burlington and Quincy railroad follows Cedar creek from the west border of the county to its junction with Coal creek. The old right-of-way closely paralleled the water grade while the new road cuts numerous headlands and is more or less independent of the immediate stream valley. Both Cedar and Coal creeks and their northern tributaries have cut completely through the drift at numerous points and expose limited sections of the Coal Measures. South of Cedar creek stream cutting is confined wholly to the drift. All of the streams have comparatively narrow valleys and alluvial deposits are of scarcely mapable dimensions. Terraces

are not prominent, but certain poorly defined gravel benches may be viewed along White and Whipporwill creeks in Wayne township forty to fifty feet above the present channel. A fairly prominent terrace may be seen along Cedar creek in Union township. Fragmentary terraces may be noted at other points but are so greatly obscured by the loess and recent wash that it is almost impossible to trace them with any degree of confidence.

East of the Albia-Lovilia divide the creeks which drain into the Des Moines, listing them from north to south, are Bluff, Gray, Miller, the Averys and Soap creeks; all flowing approximately at right angles to the divide. Here, as is the case with streams west of the divide, those draining the northern portion of the county have completely incised the drift and expose the indurated rocks at numerous points. All of the streams possess high gradients and all are yet in the down cutting stage a few miles away from the Des Moines river. Miller and Gray creeks show numerous escarpments and give a very rugged character to the adjoining topography.

The Des Moines river cuts off from the northeast corner of the county an isoceles triangle whose base is scarcely more than half a mile in length. The river flows through a broad valley bounded by low bluffs which rise gradually for some distance inland until the level of the general upland is reached some two miles back. The belt flooded by ordinary high water is small as compared with the width of the valley. At Eddyville and vicinity the valley varies from a mile to one and a half miles in width, while the actual belt subject to inundation does not exceed from one-fourth to one-half that width. A well marked terrace appears some twenty feet above low water level and can be traced more or less continuously on one or both sides of the river. Near Eddyville this terrace is often rock supported in part. Terraces at a higher level cannot be recognized.

The Chariton System.—The tributaries representing the Chariton system are unimportant. None have cut through the drift and none persist through dry seasons.

Age of the Streams.—All of the tributary streams appear to be post-Kansan. The Des Moines river alone occupies a preglacial valley.

STRATIGRAPHY.

GENERAL RELATIONS OF STRATA.

Monroe county lies well within the accepted limits of the Western Coal Field. The Des Moines river and a few of its tributaries near the northeastern corner of the county have cut entirely through the drift and Coal Measures and uncover the Saint Louis limestone. The Lower Carboniferous constitutes the country rock for less than two square miles in the county. The Coal Measures while universally present are quite generally concealed by the drift and only fragmentary exposures may be observed along the drainage lines. The most important sections occur in the northern half of the county.

The Pleistocene series is represented by an older drift sheet everywhere covered by the loess save where removed by erosion. The physiographic features in general are but little influenced by the older rocks.

The taxonomic relations of the formations represented in the county are shown in the following synoptical table:

GROUP.	SYSTEM.	SERIES.	STAGE.	FORMATION.
Cenozoic.	Pleistocene.	Recent.		Wind Deposits. Alluvium.
		Glacial.	Iowan. Kansan. Aftonian?	Loess. Drift. Gravels?
Paleozoic.	Carboniferous.	Upper Carboniferous or Pennsylvanian.	Des Moines.	Chariton Conglomerate. Appanoose Beds. Monroe Beds.
		Lower Carboniferous or Mississippian.	Saint Louis.	Limestone. Sandstone.

The two great systems of rock represented in the county are separated by an unconformity of the first magnitude. This un-

conformity means an enormous time interval during which the surface was subjected to erosion, a large proportion of the Coal Measures doubtless being removed. The entire Mesozoic and most of the Cenozoic rock systems are wholly unrepresented. The oldest rocks appear in the northeastern corner of the county, but pass out of sight almost immediately away from the valley of the Des Moines river. The general dip of the strata is to the southwest at a very low angle, scarcely more than an average of five feet per mile, while local undulations, as evidenced by coal seams, have dips which are much greater, often exceeding five degrees.

Mississippian Series.

SAINT LOUIS STAGE.

Only the uppermost member known to occur in Iowa is represented and comprises a very limited area in the immediate vicinity of the Des Moines river at Eddyville. Outcrops are confined to Gray and Miller creeks and the Des Moines river. On Miller creek south of Eddyville the following section may be observed:

		FEET.
7.	Drift and surface wash	5
6.	Shale, arenaceous, with calcareous cement	7
5.	Limestone, compact, brittle, containing pyrite balls	3
4.	Limestone, öolitic, evenly bedded and shows much shell breccia	3½
3.	Marl, containing Rhynchonella casts	½
2.	Limestone, compact, lithographic, becoming softer below	4
1.	Sandstone, in heavy beds, often exhibiting cross bedding planes, exposed above creek bed	25

All of the beds mentioned above save number 7 are supposed to belong to the Saint Louis and the sequence is believed to be fairly representative for the district. Outcrops may be noted on either side of the Des Moines river both above and below Eddyville, but none of them show any new members or any decided variations from the type section. The low terrace along the Des Moines, mentioned in an earlier portion of this paper, is supported by numbers 4 and 5 of the standard section.

Truncated headland along Gray creek, showing the Coal Measures resting unconformably upon the Saint Louis limestone. A thin seam of coal appears near the middle of the section.

Along Avery creek at Dudley, some two miles from the Monroe county line, the Saint Louis is being developed on a considerable scale. Number 6 is more perfectly indurated and with numbers 4 and 5 constitute the chief quarry rock. The Saint Louis appears farthest inland along Gray creek in the northeast quarter of sec-

FIG. 55. Saint Louis limestone in Miller creek near Eddyville. The beds dip to the southwest at an angle of five degrees.

tion 10, in Pleasant township. Here some four feet of the indurated beds of the Saint Louis may be viewed, overlain unconformably by some forty feet of Coal Measures. Beyond this point the gradual rise of the surface toward the divide with the gentle dip of the beds to the southwest effectually conceals the Saint Louis.

Pennsylvanian Series.

DES MOINES STAGE.

The Coal Measures cover practically the entire county save where removed by the Des Moines river, Gray and Miller creeks, and rest unconformably upon the Lower Carboniferous. Good exposures showing the contact between the Upper and Lower Car-

boniferous are comparatively rare and are confined to those truncated headlands which appear along Gray creek in Pleasant township. At these points the Saint Louis limestone presents a somewhat uneven surface and exhibits evidence of weathering and erosion. These observations support those made in other districts that the Coal Measures overlap unconformably the Saint Louis and the contact plane is very uneven.

The Des Moines may be divided into three sub-stages; the lowest beds consisting chiefly of shales and sandstones with several coal seams and constituting the major portion of the Coal Measure section may be designated the Monroe beds, as they are typically represented in Monroe county; a middle series typically developed in Appanoose and consisting of limestones and shales, with thin but persistent seams of coal, the Appanoose beds; and an upper conglomeratic deposit exposed at but few points and known as the Chariton conglomerate.

THE MONROE BEDS.

Standard Sections.—The best natural sections of beds referable to the Monroe sub-stage appear along Gray, Bluff, Coal, White and Whippoorwill creeks. Near the center of the northwest quarter of section 8, Pleasant township, the following strata are exposed:

		FEET	IN.
7.	Drift, exposed	5	
6.	Shale, clayey	10	
5.	Coal	1	
4.	Clay	2	6
3.	Sandstone	3	
2.	Shale	35	
1.	Coal	4	

The base of the coal seam is just above the bed of the stream.

A second section worthy of mention occurs along Gray creek in Bluff Creek township in the southwest quarter of section 23. The sequence is as follows:

		FEET.
6.	Drift	10
5.	Sandstone, shattered	4
4.	Sandstone	3
3.	Shale, blue	4
2.	Sandstone, gray	8
1.	Shale, blue, exposed	6

Section along Coal creek which shows spheroidal weathering of the sandstone.

Up the stream a short distance the shaly layers present a calcareous facies and a thin seam of coal may be viewed. Plant remains weather out of the shales, and consist chiefly of Lepidodendrons. Coal also appears lower on the stream. On the northeast quarter of the same section a seam two feet in thickness is exposed.

But few exposures of any consequence appear along Bluff creek. At the point where the Chicago and Northwestern railroad crosses the creek in section 5, Bluff Creek township, Coal Measure beds may be viewed as follows:

		FEET.
3.	Shale	4
2.	Coal	5
1.	Shale	10

All of the beds are covered by the drift, which attains a considerable thickness back from the stream.

On Coal creek near the east line of section 20 in Union township an abrupt escarpment faces the creek on the east side. Ten feet of sandstone underlain by twenty-five feet of sandy shale represent the bedded rocks. The sandstone shows a marked tendency to weather out into spheroidal bowlders. Plate X is a photograph of the section. Lower on the stream trunks of Lepidodendrons of gigantic size are strewn along the cliff face. Some of the trunks are more than two feet in diameter. The sandstone is bedded very irregularly and carries pyritic balls, fragments of Lepidodendrons and coal.

No important exposures of stratified rocks occur in Cedar township. On the east bank of White creek, in the southeast quarter of section 25 an irregularly bedded, conglomeratic sandstone outcrops some twenty feet above the creek level. The sandstone contains pyritic concretions weathered to a brownish black limonite whose fresh fractures show unaltered iron pyrites. Chert concretions varying from a fraction of an inch up to a foot across are abundant. A thin pockety seam of coal appears below the sandstone about ten feet above the creek and is underlain with a pyritiferous shale extending down to water level.

Guilford township represents a rugged topography near Coal and Cedar creeks, but exposures of the Coal Measures are unim-

portant because of the greater thickness of the drift. Near the west line of section 35 a series of thin beds aggregating a thickness of thirty feet occur in the following order from top downward: Drift, coarse sandstone, gray shale, blue shale, clay shale, coal and fire-clay. The coal is considerably iron stained. The overlying shale is highly carbonaceous and contains numerous

FIG. 56. Gigantic Lepidodendrons weathered out of the shales and sandstones along Coal creek.

clay ironstones. Down the stream in section 26 the coal rises gradually until it has an elevation of about twenty-five feet above the stream.

The Coal Measure strata may be viewed along the principal drainage lines in nearly all of the other townships, but none of the exposures are of sufficient importance to deserve individual mention.

While natural sections are not extensive and generally somewhat obscured by the drift and talus slopes, nearly all of the coal companies operating in the county have put down many drill holes of which careful records were kept and these records the coal companies have generously permitted the Survey to use freely.

The Central Coal Company has done considerable prospecting in the middle of Pleasant township and the following section may be taken as an average for the district:

		Feet.	In.
17.	Drift ending in water bearing sand and gravel below	50	
16.	Shale, dark	12	
15.	Shale, gray	21	
14.	Shale, blue, hard and calcareous	2	
13.	Shale, gray	10	
12.	Coal		3
11.	Shale, black	13	
10.	Shale, light in color	3	
9.	Shale, black	14	
8.	Hard rock	2	
7.	Sandstone	5	
6.	Fire clay	2	
5.	Shale, blue	46	
4.	Sandstone, hard	1	
3.	Coal, bony	4	6
2.	Shale, black	3	
1.	Fire clay	3	

In Bluff Creek township the Consolidation Coal Company has put down many drill holes and the upper portion of the Coal Measures has been very thoroughly explored. A drill hole put down in the southeast quarter of the southeast quarter of section 16 may be considered to be fairly representative:

		Feet.	In.
20.	Drift	25	
19.	Sandstone, gray	29	6
18.	Clay, shale	3	6
17.	Shale, dark	3	1
16.	Coal	1	9
15.	Shale, light	10	2
14.	Coal	2	
13.	Shale, dark	3	6
12.	Coal	1	3
11.	Shale, light	32	
10.	Coal		10
9.	Shale, light	21	
8.	Shale, dark	2	4
7.	Coal		6
6.	Shale	15	10
5.	Sandstone	3	

		Feet.	In.
4.	Shale, gray	13	11
3.	Coal	2	
2.	Shale, dark	49	
1.	Coal	5	
		225	2

The above section is of especial interest on account of the large number of coal seams penetrated. No other drill sections in the state show so many repetitions of coal producing conditions. In Mantua township the streams have cut well into the Coal Measures and drill sections are not so common. The Smokey Hollow Coal Company has done considerable prospecting in the vicinity of the Averys and the following section may be taken as an average.

Section in southwest quarter of the southeast quarter of section 14, Tp. 76 N., R. XVI W.:

		Feet.	In.
16,	Drift and alluvium	20	
15.	Sand and gravel	60	
14.	Clay mixture	20	
13.	Shale, black	14	
12.	Coal		8
11.	Shale, light	13	
10.	Shale, dark	5	
9.	Shale light	6	
8.	Shale, dark	6	
7.	Coal	1	
6.	Fire clay	3	
5.	Shale, dark	8	
4.	Coal	5	6
3.	Shale, sandy	4	
2.	Sandstone	21	
1.	Shale, gray	2	
		189	4

In Guilford township the Wapello Coal and Mining Company has thoroughly explored a large area along Coal creek. The drillers' log for a hole put down on the southwest quarter of the northwest quarter of section 3 gives the following sequence:

		FEET.	IN.
17.	Drift ending in sand and gravel	68	
16.	Clay shale	20	
15.	Shale, dark	4	
14.	Coal		9
13.	Clay shale	21	3
12.	Shale		9
11.	Clay shale	7	3
10.	Sandstone	4	
9.	Clay shale	14	
8.	Sandstone	3	
7.	Shale	5	
6.	Slate	3	
5.	Coal	1	6
4.	Sandstone	3	
3.	Shale	6	6
2.	Shale, dark	72	
1.	Coal	5	10
		239	10

In Troy township the Hocking Coal Company has prospected extensively along Coal creek and the adjoining territory. One of the deepest holes in the district was put down in northwest quarter of the southeast quarter of section 4 and the following beds were reported to have been penetrated:

		FEET.	IN.
19.	Drift	25	
18.	Shale, light	10	
17.	Sandstone	25	
16.	Shale, light	25	
15.	Sandstone	10	
14.	Shale, light	15	
13.	Hard rock	2	
12.	Shale, dark	43	
11.	Hard rock	5	
10.	Shale, light	11	
9.	Sandstone	10	
8.	Shale, light	8	
7.	Coal	1	
6.	Hard rock	1	
5.	Shale, light	11	
4.	Hard rock	2	
3.	Shale, dark	92	8
2.	Coal	4	4
1.	Fire clay	1	
		302	

The several ledges of "hard rock" reported by the driller should be interpreted as more or less indurated sandstone ledges. Only two seams of coal are reported, while shales and sandstones repeat themselves many times.

Monroe township is the headquarters for the Whitebreast Fuel Company of Illinois and numerous drill records are on file in their office. A hole sunk near the northwest corner of the northeast quarter of section 10 may be taken as fairly typical for the township. The record is as follows:

		FEET.	IN.
35.	Drift	71	
34.	Shale, yellow	10	
33.	Shale, gray and clayey	9	5
32.	Coal	1	9
31.	Shale, blue	1	4
30.	Coal	1	1
29.	Shale, blue	25	5
28.	Shale, black	4	
27.	Sandstone, gray	2	
26.	Shale, black	7	
25.	Coal	1	6
24.	Clay shale, light	9	6
23.	Sands'one, hard	6	
22.	Shale, dark	3	
21.	Shale, sandy light	10	
20.	Shale, dark	6	8
19.	Coal		9
18.	Shale, dark	4	7
17.	Clay shale, light	3	
16.	Shale, dark banded	7	
15.	Shale, gray	5	
14.	Coal		4
13.	Shale, dark and light below	17	8
12.	Sandstone	3	
11.	Shale, mixed	7	
10.	Sandstone	2	
9.	Shale, dark	4	10
8.	Coal	1	4
7.	Sandstone, hard	2	10
6.	Shale, dark	36	6
5.	Coal	4	2
4.	Coal, shaly		7
3.	Shale, dark above and light below	5	9
2.	Sandstone	3	
1.	Shale, dark	4	
		230	

On the upland near Foster the Coal Measures run fairly uniform and the following may be taken as an average drill section:

		FEET.	IN.
22.	Drift	90	
21.	Sand and gravel	2	
20.	Fire clay	6	
19.	Shale, gray	8	
18.	Clay shale, light colored	14	
17.	Shale, black	11	
16.	Coal	1	
15.	Fire clay	2	
14.	Shale, gray and arenaceous	22	
13.	Shale, dark	6	
12.	Coal	1	6
11.	Shale, dark	2	
10.	Sandstone, shaly	4	
9.	Fire clay	3	
8.	Shale, clayey	15	
7.	Sandstone, shaly	19	
6.	Hard ledge	1	6
5.	Sandstone	10	
4.	Shale, black	5	
3.	Sandstone, shaly	31	
2.	Hard ledge	2	
1.	Sandstone	14	
		270	

While but two seams of coal appear in the section, the drillers' record shows a number of beds of fire clay which suggest the presence of additional coal horizons. Such seams are found to occur when other drill records are examined.

From the foregoing sections it is apparent that in the order of their importance shales and sandstones constitute the bulk of the Monroe beds as developed in the county, and show all gradations from typical sandstones through shaly sandstone and sandy shales to typical shales. The sandstones present oftentimes unusual facies. At several points, notably large bowlders appear in the cliff walls and the weathering agencies bring out the bowlder character to good advantage as the matrix breaks down readily and the bowlders stand out prominently. Along Coal creek, southwest of Lovilia the sandstone presents a decidely conglomeratic appearance which on closer inspection is seen to be due to the presence of chert and pyrite balls in the form of concre-

tions. The concretions vary from a fraction of an inch to several inches across and here again weathering brings out the structure in a very striking manner. Figure 57 shows two detached blocks at close range. The sandstones often show false bedding planes on a small scale which is quite a characteristic feature of Coal Measure deposits in general. The shales vary considerably in fineness of grain and fissility. As before stated all gradations are found from shaly sandstone to almost gritless shales and they vary in color from light gray, nearly white, fire-clays through the various shades of gray and blue to the black carbonaceous

FIG. 57. Concretionary sandstone which appears conglomeratic on casual inspection, Coal creek.

shales which are generally closely associated with the coal seams. In fissility they vary from the almost structureless fire clays through the clay shales to highly fissile shale. As a rule the shales carry but a small percentage of the carbonates of lime, magnesia and iron.

In addition to the shales and sandstones occasional ledges of calcareous rock are present and usually occur as argillaceous limestone, commonly known as "cap-rock," when near a coal seam. Such ledges rarely reach a thickness greater than two feet. Last and most important from an economic standpoint are the

seams of coal, which vary in number from one to seven and possibly more when the entire assemblage of beds is taken into account. In the vicinity of both Buxton and Hilton seven seams were penetrated in sinking the prospect holes, although the entire Coal Measure series were not penetrated. In thickness the individual seams vary from a thin film or "blossom" to a maximum of seven or eight feet. The Buxton section previously mentioned shows seven seams with an aggregate thickness of thirteen feet and four inches of coal, while but one seam is of sufficient thickness to be of commercial importance. The seams also vary greatly in character; some are "bony," others contain numerous bowlders and are known as stony, while still others run high in sulphur, chiefly in the form of the iron sulphides represented by the minerals pyrite and marcasite. The latter seams when exposed to the air disintegrate rapidly and show a greenish white coating of green vitriol or iron sulphate. The greenish white coating dissolves readily and in case of continued exposure is removed or changed to limonite, which makes itself manifest by the red and yellow brown stains, characteristic of the staining done by most of the waters issuing from coal mines when they come in contact with foreign substances.

The Coal Measures thicken gradually from northeast to southwest. Away from the outcrops along the streams near the east boundary of the county the prospects rarely or never penetrate the entire series so that it is impossible to assign a definite figure for the maximum thickness of the beds.

The deepest prospects whose records are available were put down by the Hocking Coal Company and the Whitebreast Fuel Company and these scarcely exceed three hundred feet from the surface. A drill hole put down by the former company to a depth of 317 feet near the center of the northwest quarter of the southwest quarter of section 34, Tp. 72 N., R. XVII W., shows at least 272 feet of Coal Measures while the drill hole of the latter company recorded on a preceding page penetrated the Coal Measures to a depth of 212 feet. From the drill records available it is reasonable to infer that the Coal Measures attain a thickness of about 300 feet for the central portion of the county and probably exceed 400 feet for the southwest portion of the county.

Structurally the Coal Measures lie almost flat when viewed broadly, dipping to the southwest at a low angle. Local undulations are quite the rule, the wave-like undulations possessing an amplitude of from a few feet to thirty or even forty feet or more. The general trend of the waves is somewhat variable, but more commonly approximate east and west. Faults of sufficient magnitude to cut out a coal seam are unknown in the county, although there are evidences of minor movements in the sheared and "slickened" surfaces of some of the roof shales. Erosional cut-outs or unconformities are encountered occasionally, especially near the thin edge of the Coal Measures. The Chariton conglomerate is reported to fill an erosional trough, deep enough to cut out the productive measures in Appanoose county. The conglomerate extends well into Monroe county, but little is known of its relation to the workable coal, though it is believed to lie too high in the series to in any way influence mining operations in the county.

THE APPANOOSE BEDS.

According to Bain* the Appanoose beds consist essentially of limestone beds which bear a certain definite position with reference to the Centerville (Mystic) coal seam, separated by shales. The normal sequence is the "fifty foot limestone," "seventeen foot limestone," the "cap rock" and the "bottom rock." The records for southern and especially for southwestern Monroe, where the Appanoose beds would naturally be expected to occur, are very meager and it is impossible to assign limits with any degree of confidence. The beds cannot be recognized definitely within the confines of the county, but on the map were continued across the Monroe county line from Appanoose county.

THE CHARITON CONGLOMERATE.

Conglomeratic beds referable to the Chariton are known to be exposed in but a single locality in the county. A limited outcrop may be viewed along one of the tributaries of Coal creek on section 3 in Monroe township, about three miles south of Albia. The beds here exposed form projecting ledges on account of their more

* Iowa Geol. Surv., Vol V, p. 378, *et seq.*, Des Moines. 1895.

resistant character than the underlying shales. The conglomerate consists essentially of rounded limestone pebbles, fragments of coal, crinoid stems and brachiopod remains imbedded in a more or less ferruginous sandy matrix. The pebbles vary considerably in size up to two or three inches in length. Some yellowish brown magnesian limestone is present. More extensive outcrops

FIG. 53. Exposure of Carboniferous sandstone on Coal creek, in the southeast quarter of the southwest quarter of section 16, Union township, showing a local undulation.

of the conglomerate occur in Appanoose county, the nearest exposure to the above occurring in section 1, Tp. 70 N., R. XVII W. A line connecting these two points would pass about one-half mile east of the mine of the Whitebreast Fuel Company at Hilton. Although much prospecting has been done in that vicinity no trace of the conglomerate is recorded.

The Pleistocene.

The Upper Carboniferous beds present evidence of profound erosion wherever they can be viewed, which indicates an unconformity between the Coal Measures and the overlying drift. The

Pleistocene may readily be separated into the drift loess which forms a top dressing everywhere unless i removed by the streams, and recent deposits which con of alluvium and wind blown materials. The drift con far the larger portion, varying from a few feet to abo in thickness, perhaps averaging seventy feet for the ent It is thinner in the eastern portion, especially the no section, and thickens to the southwest, where the strat are rarely exposed and wells are rare which completely the glacial debris. The Albia-Lovilia divide is largel drift, the Coal Measures appearing comparatively l ravines which head into it.

The bowlder clay or drift may be referred to the Ka though numerous natural sections have been closely sc drill records closely examined there appears to be no sufficient reason for subdividing the drift, which has sible in other places. Certain sections display a heav

FIG. 59. Pleistocene conglomerate underlain with Coal Measure shales forming an escarpment across a branch of Gray creek, near Eddyville.

gravel deposit below the till sheet, but a second till sheet cannot be identified with certainty. In other places the gravels are quite completely cemented and form a conglomerate as may be well seen in figure 59 where these conglomeratic beds form a considerable fall in one of the branches of Gray creek.

PRE-KANSAN GRAVELS?

Drillers in prospecting for coal rarely keep a detailed record of the surface materials. From conversation with drillers and from natural sections and the few records giving the details of the surface formations it is obvious that the Kansan drift is pretty generally underlain with from five to twenty feet of sand and gravels which rest directly upon the bed rock. The bowlders and pebbles include many rocks foreign to the district and argue the presence of an older drift-sheet at no great distance.

THE KANSAN DRIFT.

The Kansan drift usually exhibits a lower blue bowlder clay, often very compact and hard and an upper more or less loosely aggregated portion stained yellowish to a reddish brown through the oxidation of the iron and is known as the "ferretto zone." The upper stained material is quite thoroughly leached, while the blue clay effervesces freely when treated with dilute hydrochloric acid. Pebbles and bowlders occur throughout the deposit, but large bowlders are comparatively rare. The rocks present often show facetted and striated surfaces and the granite bowlders are quite generally in an advanced stage of decay, falling to pieces when removed from their matrices. Fragments of coal and pieces of wood are not infrequent, especially in the lower blue till.

THE LOESS.

A clayey silt known as the loess veneers the drift and Coal Measures over the entire county, save where removed by erosive agencies. Where present it is fairly uniform in thickness, varying from total absence along the streams and ravines to twenty or thirty feet near the crests of the adjoining bluffs. From the face of the bluff the loess thins slightly toward the divides. In

Pleistocene may readily be separated into the drift below, the loess which forms a top dressing everywhere unless it has been removed by the streams, and recent deposits which consist chiefly of alluvium and wind blown materials. The drift constitutes by far the larger portion, varying from a few feet to about 100 feet in thickness, perhaps averaging seventy feet for the entire county. It is thinner in the eastern portion, especially the northeastern section, and thickens to the southwest, where the stratified rocks are rarely exposed and wells are rare which completely penetrate the glacial debris. The Albia-Lovilia divide is largely made of drift, the Coal Measures appearing comparatively low in the ravines which head into it.

The bowlder clay or drift may be referred to the Kansan. Although numerous natural sections have been closely scanned and drill records closely examined there appears to be no good and sufficient reason for subdividing the drift, which has been possible in other places. Certain sections display a heavy sand or

FIG. 59. Pleistocene conglomerate underlain with Coal Measure shales forming an escarpment across a branch of Gray creek, near Eddyville.

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texture the loess is sandiest near the streams and is highest in clay substance near the divides; it also increases in the sand constituent from surface to base in vertical section. These facts are well shown at many points along roadways and in railroad cuts. The clay ballast plants formerly at Maxon and Selection developed the loess high in clay characteristic of the divides.

RECENT.

The streams of the county have done comparatively little in the way of building alluvial deposits. The Des Moines river has done considerable filling and presents an alluvial belt varying from one to two miles in width. Narrow belts may be noted along Coal and Cedar creeks and the Avery. The bounding bluffs along all of the last mentioned streams retain their convex profiles and the deposits of the streams are commingled with the hillside wash.

West of the Des Moines river along the Buxton extension of the Chicago and Northwestern railway, several wave-like ridges may be observed. Similar ridges occur in the adjoining counties. The railway cuts across the end of one of these ridges and exposes some fifty feet of assorted sands and silts. While there is some evidence of sorting, no persistent stratification planes are apparent. These ridges have been ascribed to wind work because of their wave-like form and imperfectly stratified character and are fairly representative dunes. Examples are more numerous north of Eddyville, in Mahaska county.

ECONOMIC GEOLOGY.

Coal.

The coal industry in Monroe county dates from the early sixties. White in his brief sketch of the geology of the county published in 1870* states that small mines had already been opened along Bluff, Miller and Avery creeks and that the Cedar mines west of Albia were producing coal. None of the mines at that time were scarcely more than country banks and operated chiefly during the winter season to supply the local demand. The first biennial report of the state mine inspector covering the years 1880

* Geology of Iowa, Part II, pp. 267-268. Des Moines, 1870.

and 1881 contains some interesting statistics. Herein it is asserted that some thirty mines are in operation in Monroe county employing 638 men. The deepest shaft is reported to be 150 feet and was located near Albia. The total production and average price per ton are not given in the report. The number of men employed is doubtless an exaggeration.

In 1883 the laws governing the inspection of mines were so amended as to require the collection and compilation of the statistics of coal production each year and beginning with 1883 the records are fairly complete. The records available showing the progress of the industry and the remarkable prosperity at the present time are tabulated in the table below. For the years 1883 to 1889 inclusive the records are compiled from the reports of the state mine inspector, for the years 1890 to date the data are obtained from the Mineral Resources of the United States Geological Survey. Total production, total value, average price per ton, average number of men employed, and average number of days worked, are compiled for Monroe county, while total production, average number of men employed, and average number of days piled for the entire state:

MONROE COUNTY.

YEAR.	Total production in short tons.	Total value.	Average price per ton.	Average No. of men employed.	Average No. of days worked.	Total production for entire state in short tons.	Average price per ton for state.	Total No. of men employed for entire state.
1883	104,607	....	....	....	....	$ 4,457,540	....	....
1884	110,238	....	....	....	....	4,370,566	....	....
1885	113,699	....	....	....	....	4,012,575	....	....
1886	131,824	....	....	....	....	4,315,779	$ 1.25	....
1887	205,525	....	....	....	....	4,473,828	1.34	....
1888	261,[illegible]64	....	....	....	....	4,952,440	1.30	....
1889	258,401	$ 299,745	$ 1.16	....	....	4,[illegible]5,358	1.33	9,247
1890	324,031	392,078	1.21	785	197	4,021,739	1.24	8,180
1891	398,227	475,805	1.21	806	208	3,7[illegible]5,495	1.27	8,124
1892	507,106	638,954	1.26	1,112	233	3,918,491	1.32	8,170
1893	570,905	638,085	1.12	1,103	214	3,972,229	1.30	8,868
1894	505,164	559,017	1.09	1,212	172	3,967,253	1.26	9,995
1895	559,982	570,879	1.02	1,037	216	4,153,074	1.20	10,066
1896	433,520	437,490	1.01	840	188	3,954,028	1.17	9,672
1897	497,831	498,[illegible]57	1.00	986	229	4,611,865	1.13	10,703
1898	584,578	594,980	1.02	1,086	232	4,618,842	1.14	10,262
1899	689,004	725,952	1.05	1,213	221	5,177,479	1.24	10,971
1900	755,286	859,720	1.14	1,592	254	5,202,939	1.33	11,608
1901	1,038,332	1,292,508	1.24	2,319	235	5,617,499	1.39	12,653
1902	....	....	....	....	....	....	....	....

With the exception of the period of great business depression ending in 1896 Monroe county has shown a fairly uniform in-

crease in the production of coal. The average price per ton reached its lowest point in 1897, when coal sold for an even dollar per ton at the mines. Since 1898 the tonnage, price, number of men employed, and number of days worked have increased rapidly. The production for 1901 exceeds that for 1900 by more than twenty-five per cent. This unusual increase resulted very largely from the opening of mines along Bluff creek by the Consolidation Coal Company. In 1883 it may be noted that Monroe produced less than two and a half per cent of the total production, while in 1901 her output exceeded eighteen per cent of the production of the entire state.

COAL BASINS.

Miller Creek District.—In the northeastern part of the county where the coal outcrops along the streams there have been many small mines, so-called country banks. Slopes are driven either in the coal where it outcrops or, when the coal seams lie a few feet below the surface, at a small angle through the measures. In the latter case the opening is called a "rock drift." Nearly all of the mines of the Miller creek district are slopes and drifts. The coal is hauled to the surface by ropes and thus the expense of hoisting is eliminated. In the southwest quarter of the southwest quarter of section 1, Pleasant township, is a local mine known as the Bridgeport or Davis mine. This mine works the lowest seam in Monroe county. For some years it has furnished considerable coal to Eddyville. The coal is obtained by a slope, but no machinery is employed in haulage. The seam worked varies from two to four feet in thickness and has a fair roof.

The Little-Hoover Company of Oskaloosa has opened a slope west of Coalfield. The Mary Jane Coal Company has a prospect east of the Little-Hoover Company, but no large operation is contemplated.

The Central Coal Company has opened a slope on the west bank of Miller creek and considerable coal is being shipped from this mine over the Iowa Central railroad. The seam worked lies thirty-five feet below the tipple and dips at a low angle to the southwest. It is rather irregular and averages about four feet in thickness. Drill records in this locality show a great number of

coal seams, some sections penetrating as many as seven, the majority of which are not of sufficient thickness to be worked. The main entry of the Central company is driven northwest and encounters numerous irregularities. Basins of sandstone extend in a northeasterly direction and in some places are 300 feet wide. The sandstone contains many fragments of coal, pyrite balls and plant remains. The coal gradually runs out and sandstone comes in, there being no signs of cutting out by water. The roof is good and the mine is increasing its output rapidly. The coal is of good quality and is known as the Miller Creek Steam coal.

Avery Creek District.—The Smoky Hollow Coal Company has been for some years one of the largest producers of this district. Thus far the work has been carried on east and south of Avery in

FIG. 60. Approach and tipple of one of the mines of the Smoky Hollow Coal Company.

the valley of South Avery creek. The coal either outcrops in the hillsides or is covered only lightly by the drift. For six miles abandoned workings mark the outcrop and from time to time the railroad stub has been extended as new mines have been opened. The company has operated principally in sections 9, 10, 11, 13, 23, and 24 in Mantua township. At present the bulk of the coal produced is mined at slopes 4 and 6, number 5 having been recently

abandoned. Slope number 4 is located in the southwest quarter of the northwest quarter of section 11; slope number 5, in the northwest quarter of the northwest quarter of section 13, and slope number 6, in the southeast quarter of the northeast quarter of section 23. It is probable that the railroad will be extended westward up the valley and that a new slope will be opened in the southwest quarter of the northwest quarter of section 23. The company has done considerable prospecting over this township and operates a diamond drill almost continuously. The sections reported show considerable irregularity in the coal seam. The coal varies in thickness from three and one-half to five feet and is mined by the pillar and room system. All the slopes are equipped with tail rope haulage systems as the length of haul makes it inadvisable to use other than mechanical haulage. At each slope the haul is more than half a mile under ground. The tipples have long approaches in order to furnish storage room for mine cars and to secure sufficient elevation above the railroad tracks. Almost the entire output of these mines is taken by the Burlington railroad.

The employes of the company live along the line of the spur, in Smoky Hollow and Hynes City. For many years the Smoky Hollow district has been a large producer. There are many old openings on both sides of the hollow. As the coal has been worked out operations have been extended to the south and now the largest producers are several miles from the old town.

The Frederick Coal Company north of Smoky Hollow has located a shaft on the northeast quarter of the southeast quarter of section 3, in Mantua township. For a number of years this mine has been producing some coal, but recently the management has been changed. A railroad track has been built from the Burlington, new buildings have been erected and a much larger output is to be expected in the near future. Considerable coal is hauled by teams from this mine to Avery and the surrounding country. The seam worked averages over three feet in thickness and is mined longwall.

The Foster District.—The Deep Vein Coal Company at Foster operates a mine through shaft number 1. The shaft reaches a coal seam at a depth of 208 feet which averages four and a half feet in

thickness. The mine is a very old one and at present is producing but little coal. The underground haulage is by mules. The hoisting drum is seven feet in diameter and is driven through a 1-4 gearing by a 12x16 inch Ottumwa engine. Air is supplied to the mine by two fans; one fan six feet in diameter is located about 300 yards from the shaft. A five horse power gas engine drives the fan and gives satisfaction. A steam line from the boiler house to the fan would require considerable attention and would not be efficient.

A short distance east of shaft number 1, a new shaft has been sunk on the upper vein. This seam runs from one to three feet in thickness and lies about thirty feet above the lower vein. The

FIG. 61. Horse gin used in sinking a shaft near Foster.

output from shaft number 2 is small and only a gin hoist is used. At present but ten men are employed.

There are no other mines of importance in this district.

Hiteman Basin.—The Wapello Coal Company operates three mines in the vicinity of Hiteman. For some years this company has been one of the leading shipping mines of the state and its entire output is handled by the Burlington. All of the mines belonging to the company are operated through shafts. Shaft number 1 is located on the northeast quarter of the southwest quarter

of section 11, of Guilford township. This mine has been in operation about ten years and a considerable area has been worked out. The coal is hauled almost a mile under ground by a tail rope system. Trips of from thirty-five to forty cars are hauled every twenty minutes when the mine is in full operation. Shaft number 2 is located in the center of section 2. This mine is about worked out and some of the machinery is being removed to the other plants. The engine and boilers are of the Ottumwa pattern. The hoisting engine is direct connected, cylinders 14x20 inches; the hoisting rope one and one-fourth inches in diameter is wound on a six foot drum. A twelve foot fan driven by a 12x18 inch engine furnishes air to the mine.

As in mine number 1, the coal is hauled underground by a tail rope system. This consists of a three-fourths and a five-eighths inch rope wound on four foot drums driven by a 10x16 inch engine.

FIG. 62. Tipple at shaft No. 3, Wapello Coal Company, Hiteman.

The real strain in this system comes on the tail rope for there is a heavy grade in favor of the loaded trip. The tail rope is carried about 400 yards on the surface by means of pulleys and then enters the mine through a four inch pipe sunk through the covering.

Shaft number 3 is located in a basin running east and west on the southeast quarter of the southeast quarter of section 3. For several reasons it was sunk so as to penetrate the lowest point in the basin, although the coal here is very poor, containing much rock. At present all of the rock must be hoisted. The thickness of the coal in this tract is well known through the many drill holes sunk by the company. The coal runs no thicker in the basins than on the rises. The company has a Sullivan diamond drill in operation and has made a careful study of the adjacent coal lands. All of the drill records are preserved and sections are constructed showing the exact position and the thickness of the workable coal seams.

Cedar Creek Mines.—For many years there have been a number of mines operating within a few miles of Albia both north and west. The Cedar mines have produced much coal, but have been abandoned for some years because all of the coal that could be mined profitably had been removed. But two mines are operating in this field at present.

A new mine is being opened on the main line of the Burlington just west of Tower. At present no coal is being produced.

The Star Coal Company has for some years been producing coal from a shaft about two and a half miles northwest of Albia. The coal is hauled by team to Albia and to a side track on the Des Moines branch of the Burlington, where it is loaded for shipment.

The Hocking Basin.—The town of Hocking is located on a spur of the Iowa Central railway about two miles southwest of Albia. The Hocking Coal Company with central offices in Oskaloosa is the only company operating in this district. Shaft number 1 was put down and operations begun in 1899 while shaft number 2 was sunk during 1900. Both shafts are located on a low terrace along Coal creek, and are 180 and 208 feet in depth respectively. The company did a large amount of preliminary drilling so that the character and limits of the coal basin were pretty well understood.

In mine number 1 the coal seam varies from four to six and one-half feet in thickness and furnishes a good grade of steam coal. The coal floor is quite irregular on account of the numerous rolls which trend about 30° east of south. The maximum variation amounts to about twenty-five feet. Some of the rolls almost

is three feet two inches and the wheel base two feet. The hinged gate of the car is fastened by two latches of inch iron, which must be raised when the car is dumped.

Ventilation is very expensive in the larger Iowa mines on account of the number of trappers required to facilitate haulage. Unless undercasts or overcasts are to be built the only solution for the trapper problem is the automatic door. Such doors are in use in the Whitebreast mine. As haulage is in both directions the

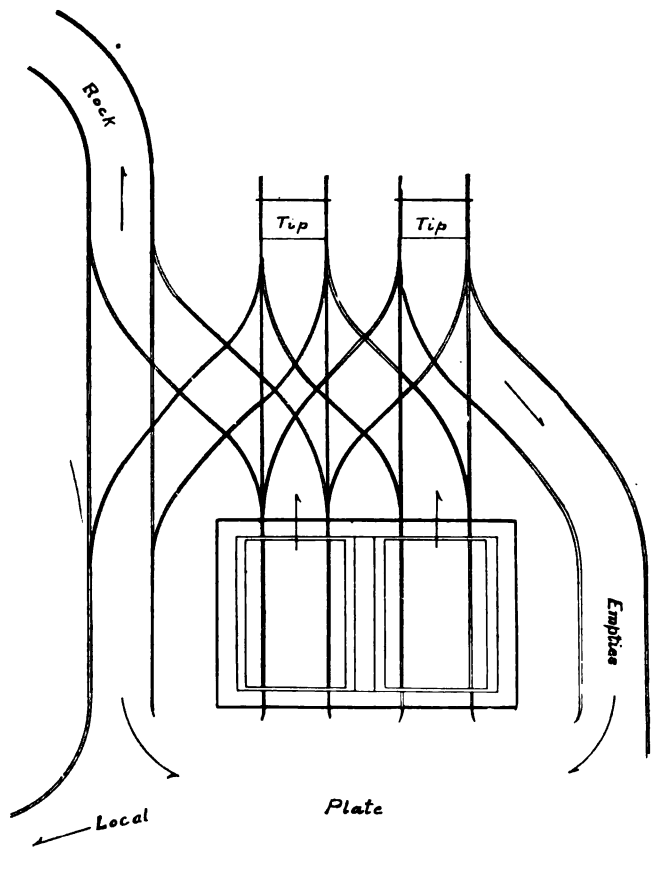

FIG. 67. Diagram showing arrangement of tracks and switches in the Whitebreast tipple.

doors must swing either way, open easily when the mule pushes against them with his head and shut promptly and tightly after the trip has passed. On each side of the door, weights are sus-

roof shale and where the settling is not carefully provided for the roof shears along the entries.

The mine is worked pillar and room system. The room centers are forty feet apart and a fifteen foot pillar is left. The side entries are run 400 feet apart.

The surface plant consists of a 12x24 inch hoisting engine and five foot drum. Haulage on the main entries is by tail rope, using five-eighths and three-fourths inch cable, driven by a 12x18 inch engine and wound on a five and a half foot drum. Air is supplied by a ten foot fan driven by a 10x16 inch engine.

An automatic dumping cage is in use. The coal is dumped directly over a standard screen or "grizzly." The screenings are elevated and graded into nut, pea and slack. Considerable rock is hoisted and must be taken off at a lower level, an arrangement which involves a loss of time.

FIG. 64. Tipple of shaft No. 2, Hocking Coal Company, Hocking.

Mine No. 2 is very similar in general character to No. 1. A conical drum, a larger fan and hand dump are the chief differences in surface equipment. Rolls and floor irregularities are of

is three feet two inches and the wheel base two feet. The hinged gate of the car is fastened by two latches of inch iron, which must be raised when the car is dumped.

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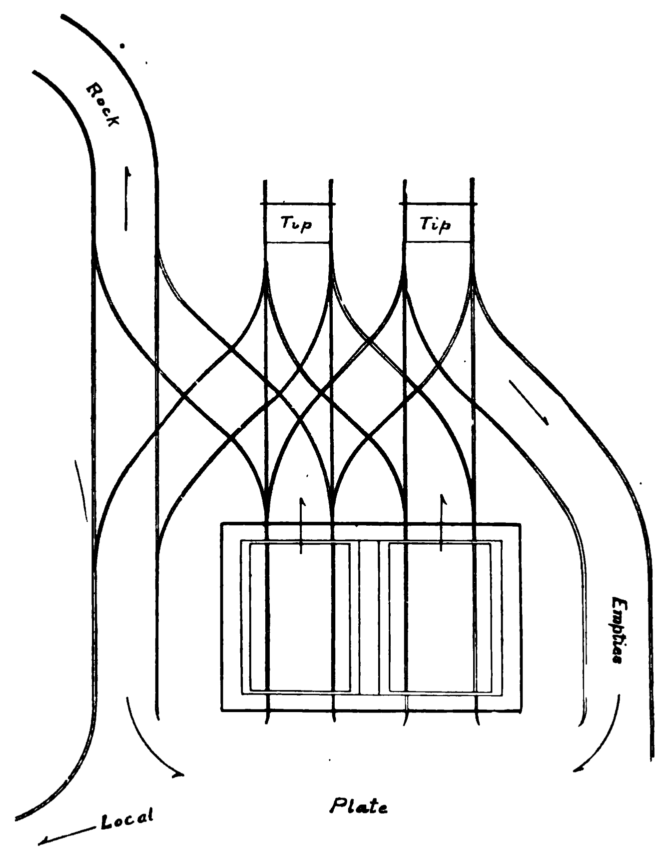


FIG. 67. Diagram showing arrangement of tracks and switches in the Whitebreast tipple.

doors must swing either way, open easily when the mule pushes against them with his head and shut promptly and tightly after the trip has passed. On each side of the door, weights are sus-

hoisting engine is a Litchfield pattern and has cylinders sixteen by thirty-four inches. The one and one-fourth inch hoisting ropes are wound on direct connected six foot drums. The air shaft is situated about 300 feet east of the main shaft and has two compartments, one for air, the other for hoisting in case the main engine be disabled. The auxiliary engine for this purpose has eight by twelve inch cylinders with a three foot drum and three-fourths inch rope. The fan is fourteen feet in diameter and is run by an engine with fourteen by twenty-four inch cylinders. All are enclosed in a fireproof house sheathed with corrugated iron. The machine shop is a well equipped building thirty-six by sixty

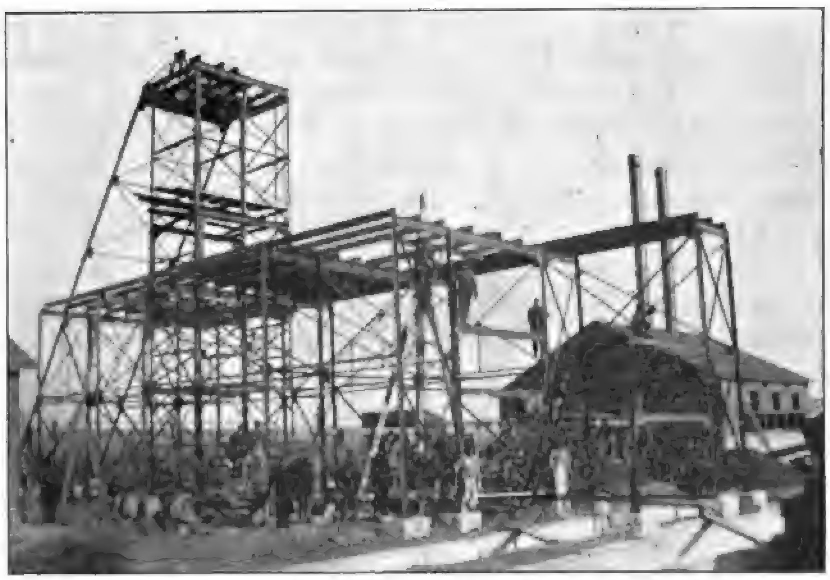


FIG. 66. Steel tipple of Whitebreast Fuel Company in course of construction.

feet and the tools and facilities for repairing mine equipment can be increased readily with increased tonnage. At present an eight by ten inch Ottumwa engine supplies power to a Champion blower and an upright post drill. All of the blacksmith work is done in this building, mine cars can be run in and repaired and tools unloaded easily.

Steel cars weighing 1100 pounds and having a capacity of 45 cubic feet are used under ground. The gauge of the mine track

In the tipple three men are employed in handling the cars; two remove the loaded car from the cage, dump it and switch it around the shaft to the cager. A steel plate is used instead of switches on the empty car side of the shaft. The arrangement of the switches in the tipple permits all possible combination in the handling of cars, except that rock, and coal for local trade must be hoisted in one shaft.

The output of the mine is lump and steam coal. The lump coal is loaded largely into box cars, which necessitates considerable labor if machinery is not used. The coal must be moved from the middle of the car to the ends in order that the car may be loaded to its full capacity and that the load may be placed over the trucks. The box car loader in use here was manufactured at the mine. The sweep is not solid to the shaft, but consists of a steel blade eight inches wide and one and three-fourths inches thick. The loader has a sweep of three feet and is operated by an eight by fourteen inch engine.

Bluff Creek Basin.—The first biennial report of the state mine inspector, printed in 1881, states that unimportant openings had been made along Bluff creek and that a local supply was obtained during the winter months from these country banks. It was not until 1901 that the district became a real factor in the coal production of the county and in 1902 the basin became a most important mining community in the state. In 1900 and 1901 the

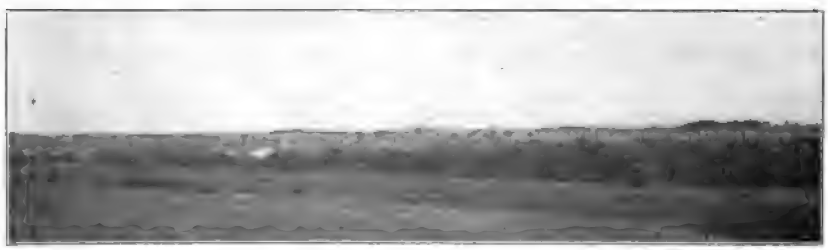


FIG. 68. View of Buxton from the west.

Consolidation Coal Company founded the town of Buxton on the extension of the Muchakinock branch of the Chicago & Northwestern railway and opened mine number 10 about two miles south of the town. In 1901 and 1902 the company put down shaft

No. 11, which is located about a mile south of number 10. Both shafts are in full operation at the present time, while shafts 12 and 13 are being sunk. Buxton is an ideal mining town. It was laid out on a rolling hillside facing north and west. Houses are better built and larger than those usually provided in mining camps. They average one full story and a half and are well kept. The streets are regularly laid out and the town as a whole presents a thrifty appearance. Mine number 10 is located on the second bottom land along Bluff creek and prospects usually show three seams of coal, while mine number 11 is located on the prairie upland and prospects in the vicinity show as many as seven distinct seams. The veins vary from six inches to above six feet in thickness. Only the lowest vein in each case is considered of sufficient thickness to warrant development under present conditions. The following section may be considered to be fairly representative of the bottom land prospects:

		FEET.	INCHES.
9.	Surface wash and drift	12	
8.	Sandstone	1	6
7.	Clay shale	3	
6.	Shale, dark	6	
5.	Clay, shale	10	6
4.	Shale, dark	9	7
3.	Coal	1	8
2.	Shale, dark	62	7
1.	Coal	6	2
		113	....

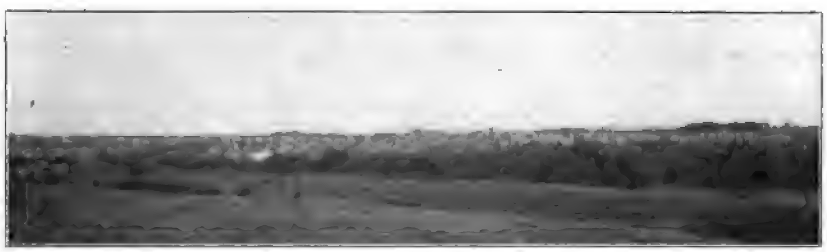
Of the upland prospects the following is about an average:

		FEET.	INCHES.
20.	Drift and loess	25	
19.	Sandstone, gray	29	6
18.	Clay shale	3	6
17.	Shale, dark	3	1
16.	Coal	1	9
15.	Shale, light	10	2
14.	Coal	2	
13.	Shale, dark	3	6
12.	Coal	1	3
11.	Shale, light	32	
10.	Coal		10
9.	Shale, light	21	
8.	Shale, dark	2	4
7.	Coal		6

In the tipple three men are employed in handling the cars; two remove the loaded car from the cage, dump it and switch it around the shaft to the cager. A steel plate is used instead of switches on the empty car side of the shaft. The arrangement of the switches in the tipple permits all possible combination in the handling of cars, except that rock, and coal for local trade must be hoisted in one shaft.

The output of the mine is lump and steam coal. The lump coal is loaded largely into box cars, which necessitates considerable labor if machinery is not used. The coal must be moved from the middle of the car to the ends in order that the car may be loaded to its full capacity and that the load may be placed over the trucks. The box car loader in use here was manufactured at the mine. The sweep is not solid to the shaft, but consists of a steel blade eight inches wide and one and three-fourths inches thick. The loader has a sweep of three feet and is operated by an eight by fourteen inch engine.

Bluff Creek Basin.—The first biennial report of the state mine inspector, printed in 1881, states that unimportant openings had been made along Bluff creek and that a local supply was obtained during the winter months from these country banks. It was not until 1901 that the district became a real factor in the coal production of the county and in 1902 the basin became a most important mining community in the state. In 1900 and 1901 the



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14.	Coal	2	
13.	Shale, dark	3	6
12.	Coal	1	3
11.	Shale, light	32	
10.	Coal		10
9.	Shale, light	21	
8.	Shale, dark	2	4
7.	Coal		6

		Feet	In.
6.	Shale	15	10
5.	Sandstone	3	
4.	Shale, gray	13	11
3.	Coal	2	
2.	Shale, dark	49	
1.	Coal	5	
		225	3

The records of the entire district show the presence of dark shale just above the lower coal seam which varies from forty to about sixty feet in thickness. This shale appears to be always present and furnishes a good safe roof.

Mines numbers 10 and 11 are thoroughly modern and up to date on every way. The tower of number 10 is of steel construction and is believed to be the highest tipple in the state, measuring sixty-nine feet to the top. Power is supplied by a battery of the three 150 horse power boilers manufactured by the National Machinery Company of Chicago. A direct connected hoisting engine of the Ottumwa Iron Works pattern with 18 by 32 inch cylinders is used. The hoisting rope is one and a fourth inch steel wire and is wound on a six foot drum. The mine cars weigh 900 pounds and will hold from 2000 to 3000 pounds of lump coal and when the mine is running full capacity an average of four cars per minute is hoisted. Cages dump automatically and one man is required at the tip to take up checks. The weigh room is on the ground level; the coal is run over a standard grizzly and arrangements are made for the separation of the screening into nut and slack, although fancy steam coal is the usual product. The plant is equipped with an Eagle Iron Works box car loader.

The arrangements at the bottom are such that all of the loaded cars are caged from one side and the empties are removed from the other. Only one man is required to cage. A double track with a one and a half per cent grade leads to the shaft, each track holding sixteen cars, the cars being controlled by sprags. The empty cars run from the cages by gravity and pass an automatic switch, after which they are shunted right and left. On the empty car side the track is lowered so that the entire entry is below the coal seam, the coal serving as the roof.

In a number of places the main entries are roofed by leaving in a portion of the vein; the shaft is protected by forty foot coal pillars; the coal runs from five to seven feet in thickness and is fairly uniform in character. Pyritic concretions and clay ironstone bowlders are not as common as in the other districts of the county. Black jack comes in as usual, but rarely exceeds six inches in thickness. The roof is uniformly good and shows but

FIG. 69. Steel tipple, showing box car loader, shaft No. 10, Consolidation Coal Company, Buxton.

few slips and cuts. It consists of a blue gray to black shale and is but slightly affected by the weather. A thin seam of false shale or draw shale varying from two to twelve inches in thickness is often present, but gives comparatively little trouble. The rock away from the bottom is wholly gobbed in the vacant rooms. Irregularities in the way of thickening and thinnings and rolls and swamps are not unlike those in other mining camps of the region. The floor inequalities rarely exceed ten or fifteen feet. The only water encountered was in the drift, principally at the air shaft. All of the water which gathers in the mine is used in wetting down the entries, although formerly a pump was operated.

The room and pillar system of mining is used, the rooms being turned forty feet from center to center and driven 210 feet.

Widening out begins after twenty feet. No undercutting or mining is done. The coal is produced wholly by shooting from the solid.

The Consolidation Coal Company has five churn drills prospecting on lands adjacent to those now being worked by the company. These drills are operated very economically by three horse power Clingman gasoline engines. The engines at 400 revolutions per minute drive the drills at 90 strokes per minute.

MINING METHODS.

The productive Coal Measures of Monroe county underlie practically the entire county. Careful exploration with the diamond drill has shown the absence of coal in certain belts. There still remain unexplored and undeveloped some very large districts, especially in the northern and western parts of the county. The extension of railroad lines will at once permit the development of large areas which have been located in these virgin districts.

Drilling.—The location of workable coal and the determination of the acreage are difficult and expensive in such a county as this. The outcrops of the Coal Measures are few, the drift is thick and erosion has cut out considerable coal. In the northeastern part of the county exploration is simpler than in the south and west. The streams of Pleasant township show coal smudge and a few outcrops. Prospecting can be done by means of drifts and pits. As the till sheet thickens it becomes necessary to use the churn drill or the diamond drill. Large areas about Coalfield and Smoky Hollow, Hilton, Foster, Hiteman and Buxton have been examined. For many years the common churn drill alone was used, but today most of the companies prefer and use the diamond drill. A notable exception is the Consolidation Coal Company, which employs only the churn drill. The value of drill sections depends upon the accuracy with which the various strata intersected are recorded and the number of drill holes per acre. An intelligent and skillful drill runner can obtain remarkably accurate results with the churn drill, but the average drill man returns reports which fail to check with subsequent records obtained by sinking a shaft. The average driller regards only the fact that he is looking for coal and considers the accurate observation and

record of other than carboniferous strata a waste of time and energy. For the driller who tries to record what he actually cuts there are many difficulties. Sludge from intersected argillaceous beds mixing with that from the bottom of the hole often causes a stratum to be recorded with an exaggerated thickness. Changes from sandstone to shale, shale to sandstone, shale to coal and coal to fire clay are easily noted and are generally accurately recorded. But the changes in the character of shales are very seldom given correctly. If the drill hole is to tell nothing more than the pres-

FIG. 70. Diamond drill of the Wapello Coal Company.

ence or absence, and the thickness of the coal seam, the churn drill can be satisfactorily employed. By the use of the diamond drill several other important observations may be made. Principal among these are the examination of the coal as to physical character and calorific value, and the examination of the rocks of

the adjacent strata. Today much of the fuel put upon the market is sold on its heating value. The careful investor and operator should know just what he is going to mine and put on the market before beginning to sink a shaft. A diamond drill hole is cheaper than a shaft and gives a fair sample for calorific tests. The friability of coal can be observed from the diamond drill core and its ability to stand shipment noted. Too much emphasis cannot be placed upon these examinations of the coal prior to the opening up of the seam. Sometimes the inability of the coal to stand shipment is not discovered until it is found that the coal is not marketable. The character of the stratum overlying the coal means much to the operator, for the expense of brushing and timbering air and haulage ways cuts down profits at a remarkable rate. In extreme cases a poor roof may prevent the mining of good coal. A shale that is very brittle or has many slips or one that carries considerable pyrite or clay ironstone bowlders causes no end of trouble, especially on entries which must be kept open for a considerable length of time. Something of the character of the shale as regards ability to withstand pressure and exposure to air currents can be learned from a diamond drill core. The amount of covering and the integrity and position of the strata with regard to water-bearing horizons must be noted with care and the shaft be located where the most favorable conditions are shown. A single drill hole means little or nothing in this district. One hole may show no coal while a few rods away a second hole may show a seam of good thickness. Many cases are on record to show how frequent have been the errors in assuming the presence of good coal over large tracts when several holes seem to show uniformity and regularity. Numerous holes must be drilled at regular intervals in order to prove the integrity of the coal seam. One operator in this field says: "We are never sure of the presence of coal until we have our entries driven and the things opened up in good shape." This fact has been appreciated by all of the companies and the numerous drill crews at work almost continuously are determining very carefully the exact boundaries of the several coal basins.

The cost of drill holes per foot varies considerably, depending principally upon the character of the materials penetrated, depth

of hole and cost of fuel and water. When the drift carries bowlders much time is lost in getting through or around them and quite often the hole is lost. The more regular the material the more easily is the drill operated and the expense is proportionately less. The depth of the hole means considerable to the drill crew. Both the shallow and the deep holes are expensive. In the former case it is necessary to move often and much time is lost in

FIG. 71. Churn drill of the Consolidation Coal Company, operated by a gasoline engine.

setting up the outfit. When the hole is very deep progress is impeded considerably by the additional friction of rope and rods. Fuel and water charges become large when either or both must be hauled some distance. Coal itself is cheap, but teaming charges add a large figure for drills operating at a distance from mines

and railroads. Gasoline has been adopted as a fuel for the churn drills operated by the Consolidation Coal Company and is giving excellent satisfaction. Three horse power Clingman gasoline engines furnish power for their drills. The cost of teaming is thus reduced to a minimum as water is required only for cooling the cylinder and for removing the broken material from the drill hole. In developing a large tract of coal land it is quite important to mark and record the exact location of the drill holes. The most accurate and only reliable way to preserve drill records is to connect all drill holes with section corners by actual surveys with the transit and to determine the elevation of the surface at each hole.

Opening the Mine.—Having the exact location and elevation of each hole and the depth of the coal seam beneath the surface, the actual elevations of the coal seams and the dips and rises can be plotted. Having made such an exploration of the coal field the location of the shaft, the planning of the bottom, the driving of entries and the actual underground layout in order to produce the maximum percentage of coal with the least expense in the haulage and drainage columns are not blind guesses. Several of the large companies are developing mines on this plan and it is the only economical method of developing coal properties where there are so many irregularities.

The coal seam may be opened by a drift, slope or shaft. When the seam crops out at a point easy of access and sometimes even when the outcrop is not easily approached by railroads the entrance may be made by a drift. When the seam does not outcrop or when the approach for tracks is not advantageous or suitable to opening by a drift, a slope is driven across the barren measures to intersect the coal seam and then follow along it. When the coal seam lies at a considerable depth and when a slope is not considered advisable a highly inclined or vertical opening called a shaft is made through the covering to the coal.

The dimensions of these openings will depend upon their uses and the quality of the material through which they are driven. Thus a very large opening cannot be easily maintained in heavy material. In such a case it must of necessity be as small as possible. An air shaft or air way will have to be driven with such an

area that it can easily furnish the required amount of air to the working places. A haulage way in which mules are used has at once its minimum height determined. A hoisting shaft may comprise one, two or three compartments. As a rule there are at least two compartments and a third is sometimes added for pipes, air or ladders. Drifts and slopes vary from five by seven feet to six by fourteen feet in cross section. Shafts vary from six by ten feet to seven by fourteen feet.

The Iowa mining laws require that there be for every seam of coal worked in the mine "two separate outlets, separated by natural strata of not less than 100 feet in breadth by which shafts or outlets distinct means of ingress and egress are always available to persons employed in the mine. * * * and if the mine is a slope or drift opening the escape shall be separated from the other openings by not less than fifty feet of natural strata. * *" *

After one of the main openings to the mine is determined the second opening is located within the limits of the law. The hoisting shaft should be located so that it will cut the lowest point of the coal basin and at the same time pass through material which is dry and can be supported easily. The requirements as to surface facilities are also important and must be considered. The grades on the railroad approaches should be light and the spur that must be built as short as possible. There should be space available for tracks, for empty and loaded cars. When the coal is hauled out through a drift or slope, tracks of sufficient length to accommodate two trips should be provided. Sometimes long trestles must be built for such tracks when underground conditions do not warrant the openings being driven at points offering greater facilities, for the simpler and cheaper installation of the top works.

Shaft sinking through the Coal Measures presents no serious difficulties, but when there is a heavy drift sheet carrying numerous bowlders many precautions must be taken. The work of sinking is all done by hand. Horse whims or gins are used to hoist the buckets, into which the broken ground is loaded. In order to sink large shafts quickly and when small shafts exceed seventy-five feet in depth steam hoists are generally installed.

*Chapter 21, Laws of 1884, Section 8.

Water is often bailed out in buckets, but sinking pumps must be hung in the shaft if there is any large inflow of water.

It pays to timber a shaft well. According to the character of the material passed through the timbering may be either heavy or light. Through the heaviest ground two by twelve inch plank laid horizontally give good support. Through very loose materials the shaft timber may be hung in sets from the top by a wire rope or each set hung from the next one above by rods. This practice is not common in the district. Slopes must be well timbered near the outcrop because from season to season there is considerable disintegration of the surface materials and where the slopes are steep there may be more or less "creeping" in the spring.

Systems of Mining.—Practically all of the coal of this county is mined by the pillar and room system; but one mine is operating longwall at the present time. The well known pillar and room system is named from the practice of first removing alternate blocks of coal, and leaving the remainder to temporarily support the roof. The rooms or openings from which the coal is removed are rectangular in shape and vary in width in this county from twenty to thirty-five feet and are driven as much as 200 feet in length. he pillars or blocks of coal remaining to support the roof vary in width from fifteen to twenty-five feet. After the rooms have been driven the length planned the coal in the pillars is mined retreating along an entry, "robbing the pillars."

The double entry system is used throughout the district. Two entries are driven parallel and from fifteen to forty feet apart. In order to allow the air to be carried as near as possible to the working face the entries are connected about every hundred feet by break-throughs. Secondary pairs of entries are driven off the main entries and are usually from 200 to 400 feet apart. Rooms may be turned from one or both of these entries. If possible the entries and rooms are driven so that the grade is in favor of the loaded car. If the grade will be against the load in either the entry or the room, the room is turned on the rise.

The rooms are driven narrow for about ten feet, that is the neck or room turning, or room door-way is only seven to nine feet wide. The work is then widened by bearing in forty-five degrees

on one or both sides until the room has the desired width. The work is then carried along straight until it holes with the room driven toward it from the next entry. Adjacent rooms are connected at frequent intervals by break-throughs in order that the ventilating current may be carried close to the working face.

The actual work of the miner consists in breaking down the coal, removing waste material, loading the coal into mine cars and the timbering of the working place. The coal may be broken down either by undercutting and shooting or "shooting off the solid." Coal may be undercut by hand or by machine. In this district there are no mining machines in operation. In undercutting coal the miner lies on his side and cuts out the bottom coal with a pick to a depth of from two and one-half to three and a half feet. He works across his room until he has removed across the entire face a triangular section about twelve inches high and two and a half to three and a half feet long or deep. He then either wedges down the coal which is undercut or bores several holes and shoots it down.

The general practice of the district is to "shoot off the solid." This simply means that the miner does no undercutting or mining, but puts in holes and shoots the coal out or off the face. The first system is the more laborious, but produces the larger percentage of lump coal and requires less shooting. It is adapted rather to thin veins than to thick ones.

In mines in which there is a parting in the coal seam the miner must give special care to the removal of all bone or shale from the coal. Bony layers often occur in the coal seam, perhaps more often occurring directly above it. In either case the bone must be removed and put in the gob. The coal is then loaded into mine cars. Tracks extend from the entry into each room and as near to the working face as possible. Very often these tracks are made of timber instead of rails. Props are supplied the men by the company, but the miner himself is responsible for the timbering of the working place. The timbers are placed regularly in order that the roof pressure may be evenly distributed, and whenever the miner notices a break in the roof he places timber so that he can support the pieces until he has removed the adjacent coal. The timbers are about long enough to extend from the floor to

tion of doors or stoppings. Doors are necessary when any travel is maintained along the second opening. When two airways intersect, one air current may be conducted over the other by the building of an overcast, or beneath by an undercast. An undercast or overcast is the most economical method of getting air across a haulage way. In case one of these plans is not used, it is necessary to put two doors in the haulage way. To open these doors when a trip is passing through and to close them immediately afterwards requires a trapper. He is paid by the day, generally one dollar per day. In large mines from ten to twenty trappers are employed when no overcasts or undercasts are built. It can be easily shown that an overcast can be paid for by the sum paid out to trappers in a year. Automatic doors are used in the Whitebreast mine at Hilton and have been described in the report on that mine. The fuel charges against ventilation are low; the principal expense is for labor and by good timbering and the construction of overcasts this can be reduced to a minimum.

Drainage.—Drainage of coal mines is effected by the collection of the mine water in the lowest points in various sections of the mine and then by a number of air or electric pumps this water may be lifted to the sump at the bottom of the shaft. Such a sump should be large enough to hold all the water produced in the mine for two days. In case of accident to the main pumps unless the sump is large, the bottom is very frequently flooded. Ditches should be dug on all wet haulage ways in order to keep the track as dry as possible. Whenever feasible, ditches for conducting water to the shaft should be made in the air ways rather than the main haulage ways. When entries are being driven in the dip, small pumps or water cars will have to be put in. Electric pumps may be economically operated when electric power is already used underground. Portable pumps driven by either air or electricity are to be recommended for the opening up of the mine.

Haulage.—Haulage underground is effected either by mules or horses or by mechanical power. Mules are preferred for short hauls, for pulling loaded cars from the working places to the switches and for distributing empty cars. But when the length

men and animals in the mine and the various harmful products resulting from the combustion of black powder or dynamite.

The circulation of air in a mine is due to the difference in pressure at different points. Such difference is developed in this district by furnaces and exhaust and force fans. A furnace at the bottom of a shaft will heat the air in that shaft to a temperature considerably above that of the mine and the atmosphere. This difference in temperature means a difference in weight of the air in the two shafts and hence a difference in pressure. The cooler air being denser, is heavier and causes greater pressure than the warm air in the furnace shaft. So the furnace shaft becomes an upcast.

The mechanical ventilators are more common and they alone can furnish sufficient air for a large mine. Most of the new fans in the county are steel and vary in diameter from ten to sixteen feet. They are generally operated by direct connection to a horizontal reciprocating steam engine. In several cases they are belt driven from steam engines. When the fan house is located over the air shaft, at some distance from the main shaft, steam must be piped to the fan engine. Owing to the loss by radiation and leaky joints there are generally many difficulties in supplying steam to the fan engine. Several gas or gasoline engines have been installed for driving fans and these give complete satisfaction. The troublesome steam line is eliminated and the gas engine can get along with less care during actual operation than a poor steam engine.

In order to properly distribute the air to the various working places underground, it is necessary that the air current be conducted in as direct a path as possible to the sections to be ventilated. When the mine is very large and there are several sections it is advisable to split the air current and ventilate each section on a separate split rather than to conduct the air through all the working places in sucession. The proper distribution of the air requires canvas, brattices, doors and overcasts and undercasts.

When air is carried along a haulage way which intersects another pasage not carrying air it is necessary that the carrying be enclosed through the intersection; this may be done by the erec-

tion of doors or stoppings. Doors are necessary when any travel is maintained along the second opening. When two airways intersect, one air current may be conducted over the other by the building of an overcast, or beneath by an undercast. An undercast or overcast is the most economical method of getting air across a haulage way. In case one of these plans is not used, it is necessary to put two doors in the haulage way. To open these doors when a trip is passing through and to close them immediately afterwards requires a trapper. He is paid by the day, generally one dollar per day. In large mines from ten to twenty trappers are employed when no overcasts or undercasts are built. It can be easily shown that an overcast can be paid for by the sum paid out to trappers in a year. Automatic doors are used in the Whitebreast mine at Hilton and have been described in the report on that mine. The fuel charges against ventilation are low; the principal expense is for labor and by good timbering and the construction of overcasts this can be reduced to a minimum.

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Haulage.—Haulage underground is effected either by mules or horses or by mechanical power. Mules are preferred for short hauls, for pulling loaded cars from the working places to the switches and for distributing empty cars. But when the length

of haul is considerable and the grade against the loads high, some mechanical equipment is usually installed. In Monroe county the tail-rope is used in almost all of the large mines. Such equipment consists of an engine, either on the surface or underground, driving the main shaft on which are two drums, both of which may be loose on the shaft or be fastened by clutches. Two ropes, the main and the tail-rope, are used in drawing out the loaded cars and pulling the empties back to the inside switch. The main rope is generally the heavier rope. In case there is a loaded trip inside to be pulled out the main rope extends from the drum to the trip. The trip is fastened to the rope by a catch, the simpler the catch, the better; the tail-rope drum is loose on the shaft and the tail-rope passes the whole length of the line around the bull-wheel at the end of the line and back to the rear end of the trip. The tail-rope acts as a break and holds the loaded trip on grades while the main rope pulls. On returning empties to the mine the tail-rope pulls and the main rope acts as a brake. The tail-rope must be twice as long as the main rope. The rope is kept off the ground by wooden or iron rollers placed every twenty to thirty feet. On the curves guide sheaves are placed so as to keep the strain on the rope uniform and to keep the rope in the center or at the side of the track. Rope haulage can be used on almost any grades and by means of branch ropes coal can be hauled from side entries.

The endless rope system is used in several mines in the state outside of Monroe county and is adapted to a very large and uniform output. As named, the rope in this system is endless or continuous. It passes around the drums on the surface or at the shaft bottom at one end of the line and around a bull-wheel at the other. There is always some device for taking up the slack in the system. Cars may be picked up individually and fastened to the rope by chains or grips or a number of cars may be hauled in trips by grip cars. Compared with the tail-rope system the endless rope system has only two-thirds as much rope, but requires two tracks,—one for empties going in and the other for loads coming out. The endless rope travels at a uniform rate of about three miles per hour, while the tail-rope runs as high as eight miles per hour. No engineer is required or attendance at the engine

while the tail-rope requires one man. The tail-rope system is better adapted to hauling from side entries and to the extension of the haulage tracks. Rope haulage can be used on almost any grade and under a great variety of conditions. Locomotive haulage requires special conditions of track, generally increased size of haulage ways and the installation of an expensive power plant and a power line of some kind. Electric haulage has given satisfaction at Pekay, where two locomotives have been in use for several years. At present there is no compressed air haulage plant in the state.

Track and Shaft Bottom.—The track underground should be kept in as good condition as possible. Poor and ill kept roads increase the friction of mine cars at a remarkable rate. On main haulage ways nothing less than a thirty pound rail should be used and where there is a very heavy haul it is safer to put in fifty pound rails. Lyes and switches should be located at convenient points wherever there are long hauls. Considerable track room should be provided at the bottom of the shaft.

The general plans for a shaft bottom may be, first, caging from one side, and, second, caging from both sides. The former plan is more economical of operation, but demands that there be such an arrangement of tracks that all of the loaded cars can be conveniently collected on one side and the empties be handled either from the opposite side or be switched easily around the shaft to the track for empties. The bottom plan of the Hilton mine already discussed is a good example of caging from one side and shows what can be done when the bottom is well designed. When the loaded cars are caged from both sides of the shaft the loaded car is supplied from one side and the empty is taken off on the other. The next loaded car is then taken from the opposite side and so on. Switches may be used at the shaft bottom, but plates of iron are commonly used for light weight cars.

Cages.—The cars are held on the cages by latches or dogs and are easily released when the car is to be removed. Quite a number of improvements have been added to the old style cage. The lifting track and the automatic dump are giving satisfaction wherever used. Self dumping cages are used by the Consolidation and Hocking companies. The details of such cages differ

considerably, but the general principle is the same. The mine car is held on the cage so that when the floor is tipped forward it will not run off. The door of the car is caught by a hook and when the car tips, the door is held up and the coal falls out upon the grizzly. The operation of the dump is very simple. The floor of the cage is mounted pivotally so that it can turn easily on a horizontal axis about three feet below the floor. Auxiliary guides run the full depth of the shaft, parallel to the main guides which direct the wheels on the extremity of the lever arm, extending to the axis about which the floor dumps. When this wheel is deflected by the guides from a vertical path the cage is deflected in the same direction. The auxiliary guides are so curved at the top of the shaft that the cage platform and the car on it are turned to an angle of about forty degrees, while the cage frame work on the main guides retains its vertical position. When the cage frame is lowered, the car on the platform returns to a vertical position as the guide wheel before mentioned following along the auxiliary guide leaves the curve and follows down the section parallel to the main guide. Such cages for automatic dumping have various patent details as to guides, levers and platforms, the general principles being the same.

In order to protect the workmen at the top and the miners who descend into the mine, safety gates, safety catches and detaching hooks are necessary. Several of the mines in this district have done much to protect their men and one company has put in safety hooks.

Top Works.—The top works and shaft house or tipple should be so planned and equipped that the maximum output of the mine can be easily and economically handled. The coal must be dumped upon the screen at such an elevation above the tracks that it can be thoroughly and quickly screened and yet at not so great a height that the lump coal in dropping through to the railroad cars is unduly shattered after leaving the screens.

Power Plant.—Hoisting engines and boilers should be simple, durable and able to stand hard usage. The boilers used in this district are generally two flue boilers or tubular boilers especially adapted to the grade of fuel used. As the quality of water varies considerably during the year and generally contains a high per-

centage of solid matter the boiler must be able to stand rougher usage than those commonly used by manufacturing establishments. The fuel used is generally slack or bony coal which is unmarketable.

The hoisting engine must be able to give rapid hoisting, a quick start and must be easily controlled. The engines of this district are of both the common types, the direct connected and the geared. When direct connected the engines must be very powerful and give high speed hoisting. They must be controlled easily and have powerful brakes in order that they can be stopped quickly and at the desired point. The geared drums permit a smaller engine to be used. In order to hoist rapidly when the gear is from one to four to one to eight the engine must be run at a high speed; such engines are easily controlled and the cage can be stopped at the top more easily than when the engine is direct connected.

Various styles of indicators are used in engine rooms to show the position of the cages in the shaft. The finger moving in the vertical line and the disk on which points are marked by the finger moving like the hands of the clock are the most common.

Transportation and Markets.—Practically all of the mines operating in the county are railway mines and produce but little coal for local consumption. In 1901 out of a total production of over a million tons less than one and a half per cent was sold to the local trade and employes. The average percentage for the entire state sold to the local trade and employes during the same year approximated twelve per cent. The railways are the chief customers and all of the large mines usually have large railway contracts which tend to steady the price and equalize the production throughout the year. In 1901 Monroe county mines were in operation the largest number of days of any of the great coal producing counties. Her record for the year was 265 days active, while the records for the whole state show an average of only 218 days active.

The general movement of the coal is to the west and north. An apparent exception is in the case of the mines at Hilton and Foster, where most of the coal goes northeast over the Kansas City division of the Chicago, Milwaukee and Saint Paul railway.

The Miller creek and Hocking mines are tributary to the Iowa Central and the total output is carried north. Smoky Hollow district, Hiteman and the Cedar creek mines are directly connected by spurs to the Burlington and the bulk of their output is carried west and distributed by the various branches of the system. The mines of the Bluff creek basin contribute their entire product to the Chicago and Northwestern railway system. The coal produced by the Consolidation Coal Company is carried to Belle Plaine and from there distributed north and west by the various branches of the system.

COAL TESTS

Samples of coal representative of the leading mines of the county were tested both chemically and calorimetrically. The chemical work was done by Mr. F. M. Weakley and the results appeared in the "Iowa Engineer."* The calorimetric work was under the direction of G. W. Bissell, professor of Mechanical Engineering, Iowa State College, and the results are published in the Iowa Engineer.† A Parr Standard Calorimeter, the invention of Professor S. W. Parr of the University of Illinois, was used. In the table below the calorimetric tests of a number of coals from other parts of Iowa and standard fuels from other parts of the country are added for comparison:

* Volume II, pp. 13-18. Ames, 1892.
† Loc cit. pp. 1-12.

COMPANY AND LOCALITY.	No. sample.	Volatile combustible.	Fixed combustible.	Total combustible.	Ash.	Sulphur.	Calorimetry B. T. U.
Consolidated Coal Co.—							
Buxton, Iowa, No. 11	1	37.09	50.83	89.92	12.08	2 27	10,585
No. 10	2	48.69	45.02	93.71	6 29	3.58	12,030
Hocking Coal Co.—							
Hocking, Iowa, No 1	3	40.02	44.86	84.88	15.12	7.41	12,087
No. 2	4	45.18	45 34	90.52	9.48	3.98	12,560
Whitebreast Fuel Co.—							
Hilton, Iowa	5	40 61	48.21	88.82	11.18	3.26	12,396
Average for five Monroe county coals	6	42.32	46.81	89.13	10.83	4.10	11,922
Centerville Block Coal Co.—							
Appanoose county	7	37.79	54.85	92.64	7 36	3.29	12,681
Corey Coal Co.—							
Webster county	8	37.98	47.98	85.96	14.04	5.90	12,431
Crawe Coal Co.—							
Boone county	9	41.46	50.33	91.79	8.21	4.16	12,729
Des Moines Coal and Mining Co.—							
Polk county	10	45.62	50.29	95.91	4.09	2 74	12,041
Eldon Coal and Mining Co.—							
Wapello county	11	42.72	47.78	90.50	9.50	4.96	13,141
Jasper County Coal and Mining Co.—							
Jasper county	12	42 24	50.27	92.51	7.49	3.08	12,134
Lodwick Bros.' Mystic.—							
Appanoose county	13	39.07	54.91	93.93	6.02	3.15	12,780
Lumsden Coal Co.—							
Davis county	14	39.06	53.46	92.52	7.48	2.38	12,097
Platt Coal Co.—							
Van Meter, Dallas county	15	40.54	51.04	91.58	8.42	3.68	11,941
Whitebreast Fuel Co —							
Pekay, Mahaska county	16	46.06	46.89	92.95	7.05	2.81	13,050
Carbon Coal Co.—							
Willard, Wapello county	17	36.94	54.20	91.14	8.86	2.86	12,245
Indiana coal, Brazil	....	37.89	55.21	93.10	6.90	1.49	....
Average four samples, Hocking Valley. O.	....	38.14	53.08	91.17	8.83	1.68	....
Pocahontas coal, West Virginia	....	18.23	75.08	93.31	6.69	0.60	....
Average of twenty-two Illinois coals	..	35.11	51.91	87.02	12.77	3.02	....
Anthracite coal	....	....	....	......	....	....	12,532
Foundry coke	....	....	......	....	.... ..	....	12,133
Lampblack	....	......	....	....	.... ..	....	14,467
Crude petroleum, Chanute, Kansas	....	....	....	....	....	....	19,488
Crude petroleum, Beaumont, Texas	....	....	....	....	....	....	19,000

The desirable qualities of a coal are a high percentage of fixed carbon and total combustibles, and low percentage of ash and sulphur. The sulphur is present usually in the form of iron sulphide or marcasite and the hydrous calcium sulphate or gypsum. In the first instance the sulphur is combustible while in the second it is not. The iron of the sulphide remains with the ash. The gypsum is dehydrated and remains with the ash. In the Monroe county coals the sulphur is mainly in the form of the sulphide. The coal of the Centerville seam or the "Mystic seam" of Bain, contains thin white partings of gypsum. Coke is the sum

of the fixed carbon and ash. None of the Monroe county coals are suitable for foundry coke, unless washed, on account of the comparatively high percentage of sulphur.

It is obvious from the above table that the actual heat value of the coal cannot be accurately determined from its chemical analysis. Nor is it possible to determine more than approximately from both chemical analysis and calorimeter tests the coal which would yield the best results when used in actual boiler tests. In a general way it may be observed, other things being equal, that the coal highest in fixed carbon gives the highest results calorimetrically, but when consumed under a boiler may be beaten by a really inferior coal. The percentage of volatile carbon affects the length of flame and coals possessing a high percentage of volatile carbon may possess a distinct advantage over better coals when used with certain types of furnaces or boilers. These are facts which should be kept in mind in the selection of a fuel for a given purpose or in the design and selection of grates and boilers when a certain fuel is to be used.

Clays.

The county is bountifully supplied with clays suitable for the manufacture of ordinary clay products and some of the more expensive wares. Almost nothing has been done toward their utilization. The clays available belong to two widely separated periods and differ greatly in character. The stratified clay-shales of the Coal Measures cover almost the entire county, although only exposed along the streamways. The most available sections appear in the northeast half of the county. Almost every ravine in the vicinity of Buxton and Hiteman exhibits liberal sections of argillaceous beds above the water line and not deeply covered by surface materials. Shales appear lower on the valley walls along Coal and Cedar creeks and their tributaries and the streams draining east from the divide. Many of the exposures are located directly on railway lines or within easy reach of such lines. None of the older clays have been used or are being used at the present time in the manufacture of clay goods.

The surface clays are second only in extent and thickness to the shales of the older rocks. The oxidized zone of the Kansan

drift often contains clays sufficiently free from bowlders and pebbles to be suitable for the manufacture of common brick and drain tile. The Kansan is almost everywhere buried by the loess which is especially adapted to the manufacture of common brick, dry press brick and drain tile. The upland loess is often very fine textured and highly prized in the manufacture of burnt clay ballast. The only clay works in the county use the loess. The somewhat assorted loess is worked into common soft mud brick and the upland loess has been used from time to time in the manufacture of burnt clay ballast. The latter material does not give satisfactory results when used for other clay products on account of its excessive shrinkage. Another source of raw materials is the alluvium modified by the wash from the loess and Kansan and furnishing a material which gives satisfactory results when wrought into common mud brick.

Clay Industry.—During 1902 only three small plants were in operation, turning out 200,000 common brick valued at $1,500. During the same time the county imported many times the above number of common brick in addition to face and paving brick, tile and sewer pipe. This is unwise economy and must correct itself in time. The various grades of brick can be made locally at least as cheaply as at the points from which they come. The raw materials are present in almost inexhaustible quantities and readily accessible; an abundance of cheap coal of excellent quality is at hand and labor is no dearer than in the neighboring counties. Monroe county should be an exporter instead of an importer of clay goods.

Until 1902 the county had been a large producer of burnt clay ballast. Upland loess along the main line of the Chicago, Burlington and Quincy at Maxon was utilized for this purpose for a number of years and the pits at this point furnished ballast for the road even beyond the limits of the county. The Davy Burnt Clay Ballast Company, whose home office is at Kenosha, Wisconsin, installed an extensive plant at Selection along the right of way of the Wabash. During 1901 the plant was in full operation, but did not operate during 1902.

The methods used by the Davy company in the manufacture of burnt clay were very simple and very effective. Some five or six

feet of the surface materials were used. A car mounted on trucks and equipped with a steam shovel and an extra long boom extending out at right angles constitutes the excavating or ballast machine. At the beginning the steam shovel cuts a trench as it moves ahead, depositing the removed materials on the opposite side of the trench by the scoop running out on the boom and dumping. The shovel car is followed by a coaling car which consists of a traveling scoop much on the same principle as the steam

FIG. 72. Burnt clay ballast machine used by the Davy Burnt Clay Ballast Company.

shovel which brings the coal to a belt conveyer, which in turn deposits a thin layer of coal over the fresh clay ridge. The track is set back from the trench and the steam shovel cuts a new swath transferring the material across the trench and depositing it evenly over the preceding layer. This in turn is followed by the coaling machine and the process repeated over and over again. The first layers are fired and the fire passes from one layer to another, the process being continuous when once well under way. The amount of coal added is intended to be sufficient to burn all or nearly all of the

types may be recognized; the modified loess-Kansan of the upland and the alluvial of the bottom and "second bottom" lands. The first covers much the greater area, while the latter is the more tractable and may be the more productive. Near the divides the clay constituent may be so great in the loess-Kansan as to render it mucky and imperfectly drained. In such instances the land is cold when wet and tends to bake when it dries, qualities not favorable to the growth of cereals. Much of the county is so greatly stream dissected that there is a considerable tendency to wash under the processes of agriculture, but affords excellent pasturage. The bottom land soils are more porous an dare usually highly productive when not too sandy. In especially wet seasons they are sometimes subject to inundation.

Potable Waters.

An adequate water supply during seasons of prolonged drouth is a serious problem for a considerable portion of the county. All of the wells thus far put down are shallow, the majority drawing their supply from the gravels and sands at the base of the drift, the sub-loessial sands or from the alluvial sands and gravels. During wet seasons all of these furnish a fairly stable supply, but during the summer of 1901 all proved more or less untrustworthy. A few wells completely penetrate the superficial materials and enter the indurated rocks with indifferent results. Stock water is obtained largely by the construction of artificial ponds. Embankments are built across the sharp draws and ravines and the storm water is conserved. This is possible because of the impervious character of the surface materials. None of the cities and towns have a sufficient supply of water for domestic use and fire protection save Eddyville, and even Eddyville has done but little towards utilizing her advantages. The domestic water supply of Albia is obtained from shallow wells and the town possesses a very inadequate water supply and waterworks system for fire protection. An artificial pond affords a reserve in case of a conflagration. The mining towns of Buxton, Hiteman and Hilton have a most precarious supply of water in dry seasons. The first mentioned town was almost wholly dependent on water brought in tank cars from the Des Moines river during 1901. It is only

sometimes attaining an inch or two in diameter. The same beds are quarried at several points along Miller creek in Wapello county and similar beds are quite extensively developed at Dudley.

Sand.

Away from the valley of the Des Moines river and its tributaries in the immediate neighborhood, building sand is a comparatively scarce article. The short stretch of the Des Moines affords sand sufficient for the entire county. Some of the larger streams in the northwest section bear gravel terraces which furnish some building sand. The loess near the more important drainage lines grades downward into clayey sands suitable for molders' purposes. The dunes along the Des Moines afford similar material.

Road Materials.

Road materials ready for use are comparatively scarce. Terrace gravels occur along some of the larger streams, but the deposits are uncertain and somewhat interrupted. The Chicago, Burlington and Quincy railway company has put down a number of test pits along Whippoorwill creek. The pits show from two to ten feet of gravel. The gravels are evidently stratified and in some of the pits fairly free from clay and silt and suitable for railway and road ballast. These gravels form a terrace some twenty to thirty feet higher than the present flood plain. As a rule the terraces at lower levels are composed of fine gravels, sands and silts and not so well suited for road work. The indurated rocks contribute nothing in the way of road materials. The Coal Measures are not sufficiently indurated and the Saint Louis not sufficiently accessible to be of importance.

For manufactured road materials the surface clay affords an inexhaustible supply of raw material suitable for the manufacture of burnt clay ballast. This topic has been discussed sufficiently under the head of the clay industry.

Soils.

As in all of the other counties of the state the soils are after all the most important asset of the county. Two fairly distinct

types may be recognized; the modified loess-Kansan of the upland and the alluvial of the bottom and "second bottom" lands. The first covers much the greater area, while the latter is the more tractable and may be the more productive. Near the divides the clay constituent may be so great in the loess-Kansan as to render it mucky and imperfectly drained. In such instances the land is cold when wet and tends to bake when it dries, qualities not favorable to the growth of cereals. Much of the county is so greatly stream dissected that there is a considerable tendency to wash under the processes of agriculture, but affords excellent pasturage. The bottom land soils are more porous an dare usually highly productive when not too sandy. In especially wet seasons they are sometimes subject to inundation.

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a question of a few years until the water problem will be more urgent than it is now. The larger towns will be obliged to provide better fire protection and to observe better sanitary practice in the disposition of sewage. To meet these requirements an increased water supply is the first essential. From the data in hand the water supply can be increased in two ways: first, by the construction of reservoirs to entrap the surface waters, and second, by the sinking of deep wells. In the construction of reservoirs to catch the storm water one precaution must be observed and that is to guard against any possible contamination over the catchment area and doubtless some system of filtering would be necessary. It would be unsafe to provide a reservoir or supply of pure water for domestic purposes and provide a reserve supply of doubtful antecedents for fire protection when one system of mains must serve for both. The impervious character of the upland surface materials renders possible the construction of surface ponds or reservoirs and perhaps affords a feasible way of augmenting the water supply. The water obtained in this way would be comparatively free from mineral matter in solution and when freed from mechanical sediments through filtration would be admirably adapted for boiler and manufacturing purposes.

The second means of water supply enlargment through deep wells is perhaps more expensive and the results are less certain. The deeper strata are practically unexplored in the county and the lower Paleozoic sandstones which afford reliable supplies of water in the north central portions of the state have not been penetrated in any of the adjoining counties. Some information may be gathered from a study of the deep wells at Ottumwa and Centerville and it is possible to estimate the probable depths at which water bearing horizons may be reasonably expected. The well put down by Morrell & Company and the one put down by the Artesian Well Company, both of Ottumwa, appear to draw their supplies from about the same horizon, the arenaceous beds in the Silurian reached at 1085 and 1015 feet below the surface respectively. Both wells give strong flows of water suitable for domestic purposes, but not adapted to boiler use until treated.

The Centerville deep wells also draw from the sandstone beds of the Silurian reached at a depth of from 1200 to 1439 feet. The

flow is not so strong as in the case of the Ottumwa wells and the water is more highly charged with solids.

For Monroe county the conditions may be expected to be about the average of Wapello and Appanoose counties and the Silurian aquifer ought to be reached at about 1200 to 1400 feet and the supply vary from 400 to 600 gallons per minute as the average supply for the two Ottumwa wells is reported to be 850 gallons per minute and for the two Centerville wells 275 gallons per minute. The water would probably be satisfactory for domestic use and fire protection, but could not be used without treatment for boiler purposes. Water from this source would probably rise to within 250 to 300 feet from the surface at Albia.

To reach the lower Paleozoic sandstone it would probably be necessary to drill to a depth of from 2600 to 3000 feet and perhaps even to a greater depth.

ACKNOWLEDGMENTS.

The writers are indebted to the mining companies operating in the county for numerous courtesies. The drill records carefully kept and secured at great expense by these companies were generously placed at the disposal of the Survey and were freely used. In fact the writers can record only courteous treatment from all those with whom they have come in contact in the progress of the work.

THE FOREST TREES AND SHRUBS OF MONROE COUNTY.

BY L. H. PAMMEL.

During the month of April I made a trip to Monroe county to study the forest trees and shrubs. Stops were made at Eddyville, Albia and Moravia. The latter place is in Appanoose county, but it was a convenient location to study forest conditions as the county line is but a few miles distant.

The small streams were, during the early settlement of the country, well wooded along their borders. Much of the best timber has long since been removed, but there is a good second growth in many places, though this has suffered during recent years because of the dry weather and overgrazing in the woods. The lumbering methods are most wasteful in many cases. There is a good demand for native lumber made from such species as the walnut, ash, elm, cottonwood, and sycamore, especially near Eddyville, where a small saw-mill is located. Along the Des Moines river there are still a few fine groves of sycamore, many of the larger trees being 12-14 feet in circumference. The chief oak is the white and red. These are also cut for lumber and fuel. Two other oaks were observed, the Bur (*Quercus macrocarpa*) and shingle oak (*Q. imbricaria*). The former makes a good sized tree on upland clay woods. The latter is a small tree and nearly reaches its northern limit near Eddyville.

TILIACEAE.

Tilia americana L.—Basswood. The species occurs along the Des Moines and its tributaries in the vicinity of Eddyville. On the moist sandy hills a second growth tree was measured and found to be two feet in circumference breast high, and thirty-five

feet high. The old trees were apparently all removed by the early settlers.

RUTACEAE.

Xanthoxylum americanum Mill.—The Prickly Ash was observed near Eddyville on the sandy bluffs and also along the borders of timber in the vicinity of Moravia.

CELASTRACEAE.

Celastrus scandens L.—The climbing Bittersweet was found in the woods near Eddyville. This plant should commend itself to cultivation.

Euonymus atropurpureus Jacq.—The Burning Bush occurs in the timber and even comes up in abundance along roadsides in the vicinity of Eddyville. It is a most desirable shrub for cultivation.

RHAMNACEAE.

Rhamnus lanceolata Pursh.—The native Buckthorn was not observed, but since it occurs to the west in Dallas county and also in Boone county it probably also occurs in Monroe.

Ceanothus americanus L.—The New Jersey Tea is common on the sandy bluffs about Eddyville.

VITACEAE.

Vitis cinera Engelm.—The Downy grape was not observed, but it occurs in Davis county along the Chariton river in the vicinity of Diff P. O.

V. riparia Michx.—Our Wild Fox Grape is common everywhere in the county near Moravia, ffddyville and Albia. Specimens of considerable size were observed. Two specimens had the following measurements, circumference (1) 14 inches at base 30 feet high, (2) 9 inches at base, 15 feet high.

Ampelepsis quinquefolia Michx.—The Virginia Creeper is common throughout the county both in upland timber and along the large streams like the Cedar and Des Moines.

SAPINDACEAE.

Aesculus glabra Willd.—The Ohio Buckeye occurs along the Des Moines, and probably also along the other streams.

Acer nigrum.—The Hard Maple is cultivated in the county and may occur wild, but certainly not an abundant tree.

A. saccharinum.—The Silver Maple is one of the most abundant of the forest trees in the county in the alluvial bottoms along the Des Moines, Miller creek and Cedar creek. It is also extensively cultivated in the county, being one of the most common street trees.

LOCALITY.	When planted.	CIRCUMFERENCE. Breast high.	Base.	HEIGHT.	REMARKS.
Albia	1870	5 ft.-2	5 ft.-7	60 ft.	Street trees.
Albia	1870	4 ft.-7	5 ft.-12	60 ft.	Street trees.
Albia	1870	5 ft.-8	7 ft.-1	65 ft.	Street trees.
Des Moines river bottom near Eddyville	1870	6 ft.-4	....	50 ft.	Native.

Some large trees are still left in the Des Moines river bottom, but the best of the trees have long since been removed. In the saw-mill yard at Eddyville there were a few good sized logs 10-12 feet long of good timber. One log measured 34 inches in diameter. This tree was one hundred years old. It is propably fair to assume that good merchantable timber of this species may be produced in 75 years. In the city of Pella in the county to the north the writer measured a soft maple that was 12 feet in circumference and 65 feet high. This tree was set out in 1847. Owing to the condition of growth the tree was not a desirable one for lumber. It shows, however, what the tree will do under cultivation.

Negundo aceroides Moench.—The Box-elder is common throughout the county along streams. It is frequently used as a shade tree in the streets.

ANACARDIACEAE.

Rhus glabra L.—The common Summach is common throughout the county.

R. toxicodendron L.—The Poison Ivy occurs most frequently in the bottoms where it climbs some of the tallest of trees. It is also found in upland woods.

LEGUMINOSEAE.

Amorpha canescens.—The common lead plant occurs on the prairies.

C. paniculata L. 'Her.—The white fruited dogwood is frequent in the county.

CAPRIFOLICEAE.

Sambucus canadensis L.—The common elder is common in low grounds throughout the county.

Viburnum opulus L.—The snowball is frequently cultivated.

V. prunifolium L.—The black haw was observed near Moravia.

Symphoricarpus vulgaris Michx.—The coral berry or Indian currant is common everywhere on the hills and dry sterile soil. Borders of woods.

Lonicera sempervirens Ait.—The trumpet honeysuckle is frequently cultivated.

L. tartarica L.—The Tartarian honeysuckle is frequently cultivated.

RUBIACEAE.

Cephalanthus occidentalis L.—The button bush is common in low grounds along the borders of sloughs.

OLEACEAE.

Fraxinus americana L.—The white ash is a rare tree in the county. It was observed along Miller's creek south of Eddyville.

F. viridis Michx.—The green ash is common along streams throughout the county and especially well developed along the Des Moines. Measurements made of some trees will be of interest.

LOCALITY.	When planted.	Age.	Diameter.	CIRCUMFERENCE.		HEIGHT.	REMARKS.
				Breast high.	Base.		
Eddyville	......	64	3 ft.	....	....	......	Log 10 ft. long
Eddyville		55	2 ft.	....	....	......	Log 10 ft. long
Albia	1870	32		4 ft.	4 ft. 9in.	60 ft.	Cultivated prairie soil

The following rate of growth was made by decades of the tree at Eddyville: First 10 years, 5 inches; second 10 years, 6 inches; third 10 years, 6 inches; fourth 10 years, 6 inches; fifth 10 years, 6 inches; sixth 10 years, 5 inches; four years, 2 inches.

R. villosus Ait.—The high bush blackberry occurs on the sandy hills near Eddyville.

Rosa Arkansana Porter—The common rose everywhere throughout the county.

R. rubiginosa L.—This sweetbriar is cultivated and rarely has escaped from cultivation.

R. setigera Michx.—The prairie rose is frequently cultivated, but scarcely hardy without protection.

Pyrus Iowensis Bailey.—The wild crab is widely distributed in the county, forming thickets.

Crataegus L.—It is probable that more species occur than the writer has been able to detect, since it is important to have the leaves, flowers and fruit.

C. mollis L.—This is the most common species of the bottoms and makes the largest tree of the genus in the county.

C. punctata Jacq.—This is the most handsome of the genus. The flat top, handsome foliage, make it a most desirable species for cultivation. It is found in bottoms.

C. margaretta.—This species is most abundant along the smaller streams in the southern part of the county.

Amelanchier canadensis Torr & Gray.—The service berry was not observed in the county, but it occurs along the Des Moines northwest of Eddyville.

SAXIFRAGACEAE.

Philadelphus coronaria L.—The mock orange is frequently cultivated.

Ribes gracile Michx.—The Missouri gooseberry is abundant everywhere in clearings along streams.

R. grossularia.—The cultivated gooseberry is hardy and frequently cultivated in the county.

R. rubrum L.—The currant is hardy and frequently cultivated.

R. aureum Pursh.—The Buffalo currant is frequently cultivated for ornamental purposes.

CORNACEAE.

Cornus sericea L.—The silky cornel forms thickets along roadsides and fences in the northern part of the county.

C. paniculata L. 'Her.—The white fruited dogwood is frequent in the county.

CAPRIFOLICEAE.

Sambucus canadensis L.—The common elder is common in low grounds throughout the county.

Viburnum opulus L.—The snowball is frequently cultivated.

V. prunifolium L.—The black haw was observed near Moravia.

Symphoricarpus vulgaris Michx.—The coral berry or Indian currant is common everywhere on the hills and dry sterile soil. Borders of woods.

Lonicera sempervirens Ait.—The trumpet honeysuckle is frequently cultivated.

L. tartarica L.—The Tartarian honeysuckle is frequently cultivated.

RUBIACEAE.

Cephalanthus occidentalis L.—The button bush is common in low grounds along the borders of sloughs.

OLEACEAE.

Fraxinus americana L.—The white ash is a rare tree in the county. It was observed along Miller's creek south of Eddyville.

F. viridis Michx.—The green ash is common along streams throughout the county and especially well developed along the Des Moines. Measurements made of some trees will be of interest.

LOCALITY.	When planted.	Age.	Diameter.	CIRCUMFERENCE.		HEIGHT.	REMARKS.
				Breast high.	Base.		
Eddyville	......	64	3 ft.	....	....	......	Log 10 ft. long
Eddyville		55	2 ft.	....	....	......	Log 10 ft. long
Albia	1870	32		4 ft.	4 ft. 9in.	60 ft.	Cultivated prairie soil

The following rate of growth was made by decades of the tree at Eddyville: First 10 years, 5 inches; second 10 years, 6 inches; third 10 years, 6 inches; fourth 10 years, 6 inches; fifth 10 years, 6 inches; sixth 10 years, 5 inches; four years, 2 inches.

Syringa vulgaris L.—The lilac is frequently cultivated in all parts of the county.

BIGNONIACEAE.

Tecoma radicans Juss.—The trumpet creeper is cultivated, but not indigenous so far as I know.

Catalpa speciosa Warder.—The catalpa is frequently cultivated and hardy. A tree measured in Albia was 5 feet 11 inches in circumference and fifty feet high.

URTICACEAE.

Ulmus fulva Michx.—The slippery elm. Common on the hills. One of the older trees on sandy hills at Eddyville measured 3 feet in circumference and 35 feet high.

Ulmus Americana L.—American elm. Abundant throughout the region, especially in low grounds along streams. A rapid growing species. The following are some measurements taken at different points:

LOCALITY.	When planted.	Age.	Diameter.	CIRCUMFERENCE.		HEIGHT.	REMARKS.
				Breast high.	Base.		
Albia	1870	82		4 ft. 10 in.	5 ft. 8 in	65 ft.	
Moravia		80		3 ft.	4 ft. 10 in.	40 ft.	Forest clay soil
Moravia		85		2 ft. 5 in.	3 ft. 2 in.	55 ft.	Clay soil.
Moravia				3 ft.	3 ft. 6 in	40 ft.	Clay soil
Moravia		150	3 ft.			75 ft.	Clay soil.
Eddyville				6 ft. 10 in.		50 ft.	Clay soil.
Eddyville		58	2 ft.?				Log.
Eddyville		115	3 ft.			75 ft.	Bottom forest
Evans				12 ft. 3 in.		75 ft.	
Evans				6 ft. 4 in.		60 ft.	
Evans		110		2 ft. 8 in.			

A log at Eddyville made the following rate of growth, by decades: First 10 years, 4 inches; second ten years, $4\frac{1}{2}$ inches; third 10 years, $4\frac{1}{2}$ inches; fourth 10 years, 6 inches; fifth 10 years, 4 inches; in the last eight years, 4 inches.

Ulmus racemosa Thom.—Corky bark elm. This species is said to occur along the Des Moines, but I did not see specimens.

Celtis occidentalis L.—Hackberry. A frequent tree along the bottoms and uplands. The following measurement of a large tree growing in the bottoms was made at Evans: Circumference, 7 feet, 2 inches; height, 70 feet.

Morus rubra L.—Was not observed, but a cultivated specimen was found at Albia.

PLATANACEAE.

Platanus occidentalis L.—Sycamore. Abundant along all of the streams. Large and unique trees are found along the Des Moines near Eddyville. The bottoms are frequently cleared leaving the large trees standing, surrounded by fields of maize. A large tree between Eddyville and Harvey measured 12 feet in circumference and 75 feet high. The tops had been broken off by the winds.

JUGLANDACEAE.

Juglans cinerea L.—Butternut. The butternut occurs on the bluffs and higher valleys throughout the region. The trees do not attain great size, a single one of the older trees measured had a circumference of 4 feet 2 inches, and height of 35 feet.

J. nigra L.—Black walnut. The black walnut is much more abundant than the butternut. It occurs in the valleys, especially the alluvial bottom throughout the region. A cut log had a circumference of 3 feet 9 inches, age 38 years. A second cut log had a circumference of 4 feet, age 50 years. The log was 10 feet long.

Carya alba Nutt.—Shell-bark hickory. The shell-bark hickory is the most common of the genus in Monroe county. The following measurements were made:

LOCALITY.	Age.	Diameter.	CIRCUMFERENCE.		HEIGHT.	REMARKS.
			Breast high.	Base.		
Moravia		......	2 ft.	2 ft.	30 ft.	Clay soil second growth,
Moravia	....	......	2 ft. 7 in.	2 ft. 10 in.	35 ft.	Clay soil second growth.
Moravia	..	......	4 ft. 9 in.	6 ft.	65 ft.	Original forest.
Moravia	75	......	1 ft. 6 in.	....	60 ft.	Original forest.
Moravia	80	..	1 ft. 10 in.	....	69 ft.	Original forest.

Carya porcina Nutt.—Pig-nut. The pig-nut is distributed over the county in upland woods and in the higher wooded valleys. A second growth tree in Moravia measured 2 feet 6 inches in circumference and had a height of 45 feet.

CUPULIFERAE.

Betula nigra L.—River Birch. The species is common along the Des Moines. It finds considerable use for lumber.

Corylus americana Walt.—Hazlenut. Common throughout the region in upland woods.

Ostrya virginica Wild.—Ironwood. In upland woods not infrequent.

Quercus alba L.—White oak. Occurs throughout the county in upland woods.

Q. macrocarpa Michx.—Bur oak. The bur oak occurs chiefly in upland woods. It was noted at Albia, Moravia and Eddyville. At Moravia the trees are second growth. A few measurements were taken:

LOCALIYT.	When planted.	Age.	Diameter	CIRCUMFERENCE.		HEIGHT.	REMARKS.
				Breast high.	Base.		
Moravia	...	....	......	1 ft. 8 in.	... .	35 ft.	Black soil.
Moravia	......	..	......	11 in.	....	24 ft.	Black soil.
Eddyville	..	....	.....	12 ft. 8 in.	....	50 ft.	Short tree. Sandy soil.
Eddyville	....		..	8 ft.	....	45 ft.	Sandy soil.

Quercus rubra L.—Red oak. Found chiefly in upland woods and along smaller streams. The trees observed were all second growth. A tree at Moravia measured 3 feet 2 inches in circumference breast high, with a height of 45 feet, probably 40 years old.

Q. imbricaria Michx.—Shingle oak. The shingle oak occurs in scattered groves over the entire wooded section of the county. The trees are, however, small.

SALICACEAE.

Salix nigra Marsh.—Black willow. Along the Des Moines.

S. amygdaloides And.—Along the Des Moines.

S. alba L. var. *vitellina* Koch.—Commonly cultivated.

S. longifolia Muhl.—Common along streams.

S. rostrata Richards.—This species is rare in the county. Observed at the base of a sandy bluff in northwestern part of Monroe county, near a spring.

S. humilis Marsh.—Prairie willow. High banks along the Des Moines river.

Populus alba L.—White poplar. Frequently cultivated and occurring as an escape from cultivation. A single large cultivated tree in Albia, set out about 1869, measured 9 feet 9 inches breast high in circumference and 60 feet high.

Populus tremuloides Michx.—Aspen. Not observed in the county, but was noticed across the border in Mahaska county.

Populus monilifera Ait.—Cottonwood. The cottonwood occurs throughout the county, usually along streams. The tree grows rapidly and attains a large size. The following measurements were made:

LOCALITY.	Age.	Diameter.	HEIGHT.	REMARKS.
Moravia	200	4 ft.	90 ft.	Forest in bottom.
Eddyville	140	4 ft.	.....	Log from forest Des Moines bottom.

The following table shows the growth by decades:

YEARS.	INCHES.	YEARS.	INCHES.	YEARS.	INCHES.
10	4	10	3	10	5
10	3	10	4		
10	2½	10	4		
10	3	10	4		
10	3	10	3		
10	3½	10	4		
		10	3		

CONIFEREAE.

Pinus strobus L.—White pine. This species is occasionally cultivated, but none of the trees have attained any size. A large tree which was set out in 1872 had a circumference of 4 feet 5 inches, and a height of 50 feet.

P. sylvestris L.—Scotch pine. This species is cultivated more frequently than the preceding, but it does well only under favorable conditions. Some good trees were observed in the vicinity of Eddyville on the sandy slopes. Two of these trees were measured. Circumference, 3 feet 8 inches; height, 38 feet. A second tree on Mr. Long's place measured 5 feet 6 inches in circumference and 40 feet in height. They were set out in 1867. The trees are apparently healthy, in fact are as good as any I have

seen in the state. The ground is underlain with a fine sand with an abundance of moisture. Numerous springs occur at the base of the hill.

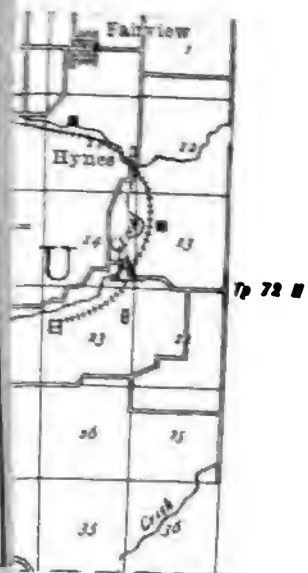
P. austriaca Hoss.—Austrian pine. The Austrian pine is frequently cultivated, but there are not nearly so many specimens as of the Scotch pine.

Thuya occidentalis L.—Arbor vitae. Mr. De Long set out quite a group of Arbor vitae on the northwest slope of his place in sandy soil in 1867. The trees have done remarkably well, far better than the balsam. Three trees were measured, but they show but little range. Circumference 1 foot 10 inches, 35 feet high; circumference 1 foot 8 inches, 32 feet high; circumference 1 foot 11 inches, 35 feet high.

Juniperus virginiana L.—Red Cedar. The red cedar is frequently planted. I saw no native trees, but old settlers tell me that they occurred on Cedar creek.

Picea excelsa Link.—Norway spruce. Here as elsewhere in the state the Norway spruce was one of the few conifers set out in early days. It is not a valuable tree except under favorable conditions. Mr. De Long's place is a favorable one. The sandy soil and the sheet of water below make it a good location. A few measurements show that a good growth has been made; circumference 6 feet, height 55 feet. Trees set out in 1867. A second tree had a circumference of 4 feet 4 inches, 60 feet high. Set out in 1867.

Abies balsamea Miller.—Balsam fir. Like the spruce the early settlers planted this species but it is less satisfactory than the Norway spruce. Few of the trees remain. Mr. De Long's place is favorable, but of the numerous trees set out but three remain. One was dead, one partially, and one still green. Measurements of the three trees were as follows: Circumference 3 feet; height 35 feet; circumference 2 feet; height 40 feet; circumference 3 feet; height 40 feet. These trees were set out on a sandy slope in 1867.



S. W. BEYER

AND

L. E. YOUNG.

1902.

Scale 1:[illegible]

5 Miles

5 Kilometers

LEGEND

GEOLOGICAL FORMATIONS

DES MOINES

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